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CLASSIFICATION OF SCALE INSECTS OF THE SUBFAMILY ORTHEZIINAE [1]

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INTRODUCTION

The subfamily Ortheziinae forms a well defined group within the family Coccidae. The group is of interest not only on account of the wide distribution and fully recognized injuriousness of certain of its members, but because of the characteristic and even, for Coccidae, beautiful superficial appearance produced by the usually sharply defined, platelike tufts of waxy secretion, and the rather unusual morphological modifications of the body structure. The group has a further interest in this country in that, so far as its species are known, it is predominantly American, presumably both in origin and in development.

Although only one of the species at present found within the United States, the so-called greenhouse Orthezia, has attracted attention as a scale pest of major importance, the presence of a relatively large number of species in the Southwestern States and the potentially wide host range indicated for the subfamily by the known host records, combined with the marked increase in agricultural development in this southwestern region in recent years, at least suggests the possibility that the members of the subfamily may take on a new economic importance if the proper conditions for the increase and spread of some of the species found there are created through the continued expansion of agricultural activities in this region.

ILLUSTRATIONS

In making use of the illustrations certain factors should be taken into consideration. Practically all of them, both the photographs and the drawings, have been made from dried specimens, most of which have been preserved for years. It is difficult, with many of the species, to obtain perfect specimens even in life, and the condition after years of storage is usually such that few, if any, of the specimens shown in the photographs are perfect. The same and other conditions have affected the specimens which have been mounted, with the result that hardly any of the drawings of the insects as a whole are to be regarded as representing the structures figured with entire correctness and in precisely coordinated relation to each other. Thus, while the dorsal and ventral spine bands in the abdominal region are believed to be depicted in fairly accurate fashion, it has frequently been quite impossible, from the material at hand, to make absolutely certain of the size, shape,

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[2] Only the availability of the large collection of Coccidae built up during past years through the work of the Bureau of Entomology and through gifts of specimens to it and to the United States National Museum by various individuals has made this paper possible. Since beginning the study the writer has become indebted to Prof. T. D. A. Cockerell, Prof. E. O. Essig, and Prof. G. F. Ferris, in the United States, to Mr. Adolph Hempel, of Sao Paulo, Brazil, and to Dr. F. Silvestri of Portici, Italy, for the loan or gift of valuable specimens which have greatly aided the work on the group. The writer has been able to examine either type or apparently authentic material of 34 of the 40 species accepted as valid in this paper, including all but 2 of the species of Orthezia.

Most of the figures included in this paper to illustrate the general appearance of the body and particularly the arrangement of spine bands and clusters in the species discussed have been prepared, under the direction of the writer, by Miss Sarah Hoke, while Miss M. E. Stehle (Mrs. J. C. Hamlin), Miss A. I. Shoemaker, and Miss Leola J. Kruger have each contributed a few. Nearly all of the photographic illustrations have been prepared by J. G. Pratt.

Owing primarily to space limitations it has been found necessary to reduce the bibliographical citations under each species to the few required to show the original publication of the description and responsibility for any accepted synonymy. Many references will be found in the Fernald "Catalogue of the Coccidae of the World," a publication almost always accessible to working entomologists, and many others may be obtained by consulting the papers of the present-day active workers on the Coccidae.

and position of the anterior bands and spine clusters, particularly in the ventral thoracic and head regions, and the arrangement of these as figured will probably prove to be only approximately correct when perfect specimens of each species are available for study. Again, owing to the viccissitudes incurred during the mounting of specimens often imperfect, the body has frequently become distorted in such a fashion as to make its true outline very uncertain and, in consequence, the body outline of any species, as shown in its figure, should not be regarded as necessarily correct, nor should any variation in this among species be regarded as of taxonomic importance. The figures showing dorsal and ventral halves of the body are also incomplete in that they make no attempt to show and locate all of the setae and disk pores present in the derm of the insect, usually showing only those that appear to have some obvious or possible importance in relation to their classification. In spite of any such deficiencies, it is believed that these figures, if used in connection with the text, will greatly facilitate the recognition of the different species discussed in this paper.

In the detail drawings of the spines from certain parts of the body of each species, an attempt has been made to show the average condition for each. Usually, however, since nearly all of these spines have not only a curved longitudinal axis, but vary from circular to oval in cross sections at different points, the angle at which any spine lies under the microscope has a marked influence on its profile and should be given consideration when the spines are under examination.

Most, but not all, of the photographic illustrations show the insects enlarged approximately seven and one-half times. The text should be consulted when accurate information as to the size of a species is desired. The enlargement in the drawings varies and is indicated for each.

GEOGRAPHICAL DISTRIBUTION

The original natural distribution of the species of this subfamily, necessarily inferred in the case of some of the more widely distributed forms such as *insignis*, shows two rather striking characteristics which deserve mention. Thus, so far as records are available, there are no truly indigenous species in the Ethiopian, Oriental, and Australian regions, and the known species are predominantly Nearctic and Neotropical in distribution and only secondarily Palaearctic.

The 40 members of the subfamily definitely recognized at present are given in the list below and their general natural distribution throughout the world is indicated on the accompanying maps (figs. 1 and 2).

ORTHEZIA BOSC D'ANTIC

Orthezia s. str.
- *annae* Cockerell.
- *arenariae* Vayssière.
- *artemisiae* Cockerell.
- *balloui*, new species.
- *boliviana*, new species.
- *caudata* Ferris.
- *cheilanthi* Tinsley.
- *galapagoensis* Kuwana.
- *garryae* Cockerell.
- *graminis* Tinsley.
- *grandis* Hempel.
- *insignis* Douglas.
- *lasiorum* Cockerell.
- *longipes* Hempel.
- *mexicana*, new species.
- *minor*, new species.
- *monticola* Cockerell.
- *nigrocincta* Cockerell.
- *nuda* Ferris.
- *olivacea* Cockerell.
- *praelonga* Douglas.
- *pseudograminis*, new species.
- *solidaginis* Sanders.
- *sonorensis* Cockerell.
- *tillandsiae*, new species.
- *ultima* Cockerell.
- *urticae* (Linnaeus).
- *varipes* Leonardi.
- *yashushii* Kuwana.

Arctorthezia Cockerell.
- *cataphracta* (Shaw).
- *occidentalis* Douglas.

NEWSTEADIA GREEN

- *americana*, new species.
- *floccosa* (De Geer).
- *tristani* (Silvestri).

MIXORTHEZIA, NEW GENUS

- *cubana*, new species.

ORTHEZIOLA SULC

- *fodiens* Giard.
- *vejdovskyi* Sulc.

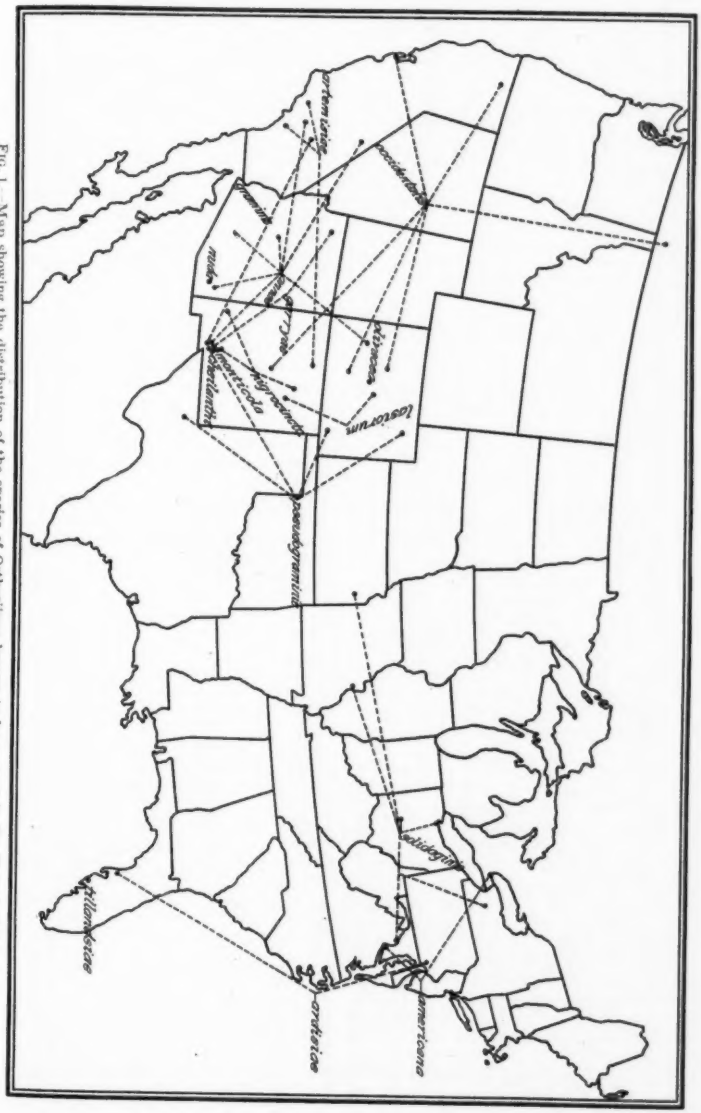


FIG. 1.—Map showing the distribution of the species of Ortheziinae known to be present in the United States

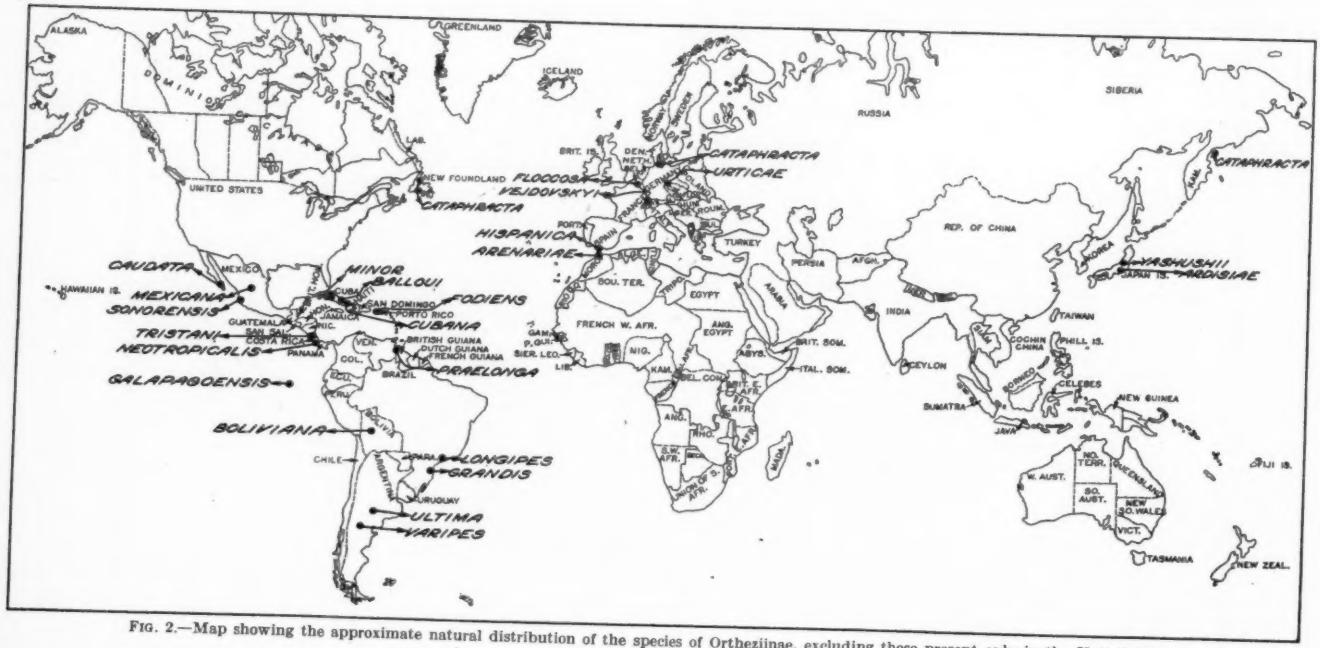


FIG. 2.—Map showing the approximate natural distribution of the species of Ortheziinae, excluding those present only in the United States

NIPPONORTHEZIA KUWANA

ardisiae Kuwana.
hispanica (Silvestri).
neotropicalis (Silvestri).

One species, *Orthezia cataphracta*, is known through definite records to be Holarctic in its distribution. A second species, *Nipponorthezia ardisiae*, has been found both in Japan and in the Eastern United States and, as its origin is uncertain, although the present evidence favors the assumption that it is probably native to the United States and was introduced into Japan, its occurrence in both localities has been indicated. The distribution of each of the other species is shown by the use of its name a single time only, this, in each case, being placed as nearly as possible at the location indicated by the known collection records, or as nearly as possible at the center of its known distribution, where the species is already widespread. In addition to the one Holarctic species and the Japanese species mentioned, 17 species are to be credited to the Nearctic region, nearly all of which occur in the southwestern portion of the United States or in northern Mexico. One other species, *tillandsiae*, from Florida, should possibly be included here, but in its general appearance, its morphological characters, and its host relations it seems to belong more properly in the upper, insular, section of the Neotropical region with *balloui* and *minor*. Including these 3 species, 14 species are to be credited to the whole Neotropical region, making a total of 33 species known to occur on the continents of North and South America and adjacent islands. This leaves, aside from the Holarctic species already mentioned, only 7 species represented in the Palaearctic region, one of which is known from a single locality in Spain, one from a single locality in Morocco, and two from Japan, while the other three are known from sufficiently separated areas to indicate their wide distribution through at least the western portion of the Palaearctic region. The summary of the distribution of the species by regions therefore stands as follows: Palaearctic, 7 (including 2 also Nearctic); Nearctic, 19 (including 2 also Palaearctic); Neotropical, 14; and Insular, 1 (*galapagoensis*).

The actual known distribution of a few of the more important species is shown with precision in small outline maps accompanying their descriptions.

HOST RELATIONSHIPS

The records of the infestation of various plant hosts by the 40 species of this subfamily come from such a wide range of families in the plant kingdom that about the only generalization possible for the subfamily is that some one of its members might, under proper conditions, attack almost any of the higher growing plants. Even Coniferae, although not included among the hosts of any of the described species, have been reported as harboring a species of Orthezia. A summary of the records for the various species indicates, however, a predominance of certain plant families as hosts for the members of the subfamily. Conclusions regarding such predominance are, of course, accurate only in so far as our present knowledge extends, and can not be understood to indicate definitely the host limitations of any one of the species, or even necessarily its preferred host plants, since, in the case of the more important and more widely distributed species, such as *insignis*, *praelonga*, and *urticae*, the range of host families is rather extended and appears to depend almost as much upon the availability of the host to the insect as upon any other factor.

Of the known species of Ortheziinae, 8 appear to have members of the Compositae as the only or predominant hosts; 4 have species of the Gramineae as the hosts; 2 have members of the Rubiaceae as the only known hosts; 2 more have genera in the Chenopodiaceae as their only hosts; and members of the Bromeliaceae, Euphorbiaceae, Fagaceae, Melanostomaceae, Myrsinaceae, and Polypodiaceae are infested by one coccid species to each family. In the case of 6 of the described species, including the two important pests *insignis* and *praelonga*, it is not possible to cite any one family as including the most acceptable hosts, although, as recently pointed out by E. E. Green for *insignis*, the tendency in its case appears to be to prefer as hosts members of the families Acanthaceae, Compositae, Verbenaceae, and possibly, in addition, Solanaceae, and, in the case of *praelonga*, members of the Euphorbiaceae. The plant hosts of the remaining species are unknown, owing either to failure or inability to make a record at the time of collection, or to the finding of the species in ants' nests not directly associated with any host plant.

The discussion of the classification and of the detailed distribution and host relationships of the subfamily and its included species follows.

SUBFAMILY ORTHEZIINAE

The members of this subfamily may be distinguished from other Coccidae by the following combination of characters:

Adult female with fully developed abdominal spiracles; anal ring with a pore band present, more or less distinctly divided into right and left halves and these into inner and outer sections and bearing 6 anal ring setae; antenna with a single stout terminal spine or seta; each leg with at least the trochanter and femur fused into a single part; beak 1- to 2-segmented; derm pores of the quadrilocular disk type, rarely with some multilocular or clustered pores; body with a few slender setae and numerous rather stout spines, the latter grouped in definite bands and clusters; external secretionary covering, in so far as developed, made up of definite tufts or plates of waxy secretion forming a distinct pattern varying with the species; mature insect with a prominent posterior ovisac, often much longer than the insect itself, this secreted by a well developed ventral ovisac band; active throughout the whole adult stage.

Larva similar to adult female in the possession of the abdominal spiracles, anal ring with pores and setae, and spines in more or less definite clusters; antennae 3- to 6-segmented.

Distinguishing characteristics of adult males not sufficiently known to permit their differentiation from the males of other groups having compound eyes and abdominal spiracles. An incomplete diagnosis of those of Orthezia may be found under the discussion of that genus.

In the possession of the abdominal spiracles, presumably in all stages, and in the possession of the compound eyes, accompanied by ocelli, in the adult males, the members of this subfamily show a rather close relationship with the group of Coccidae at present placed under the subfamilies Monophlebinae and Margarodinae, and it appears that the subfamily Ortheziinae is more closely related to this group than to any other within the family. The species of Ortheziinae depart distinctly from the Monophlebinae and Margarodinae in having, in both adult female and larva, an anal ring with distinctly developed pore bands and anal ring setae. The fusion of trochanter and femur, although characteristic for the subfamily and accompanied by a comparable fusion of the tibia and tarsus in all of the genera except Orthezia, is not distinctive, as a similar coalescence of parts of the legs occurs occasionally in some other subfamilies, although in such cases this coalescence is usually accompanied by a marked reduction in the size and functioning capacity of the legs.

The known genera of this subfamily may be distinguished by the following key:

KEY TO GENERA OF ORTHEZIINAE

a. Tibio-tarsal articulation distinctly developed; antennae usually normally 8-, rarely 7-segmented, if the latter, the basal segment not very large and prominent, and the abdomen with 7 or 8 pairs of spiracles ..... ORTHEZIA Bosc.

aa. Tibio-tarsal articulation wanting, or at most suggested by a transverse line, these two parts of the leg rigidly fused; antennae usually normally with fewer than 7 segments, or, if with this number, the basal segment very large and prominent.

b. Antennae 6- or 7-segmented; with 5 pairs of abdominal spiracles, these present on the anterior segments ..... NEWSTEADIA Green.

bb. Antennae at most 4-segmented.

c. With 8 pairs of abdominal spiracles as in Orthezia; antennae 4-segmented ..... MIXORTHEZIA, new genus.

cc. With fewer than 8 pairs of abdominal spiracles; antennae actually 3-segmented.

d. Antennae apparently 4-segmented; eyestalk and pseudo-basal antennal segment fused; beak 1-segmented; anal ring with 6 subequal setae; abdominal spiracles uncertain ..... ORTHEZIOLA Sulc.

dd. Antennae 3-segmented; eyestalk and basal antennal segment distinctly separate; beak distinctly 2-segmented; anal ring with the intermediate pair of setae much smaller; with 6 pairs of abdominal spiracles ..... NIPPONORTHEZIA Kuwana.

GENUS ORTHEZIA BOSC D'ANTIC

Reference.—*Orthezia* Bosc, 1784, Jour. Phys. 24: 173.

Synonyms.—*Dorthezia* Bosc, *Cionops* Leach, *Cyphoma* Gistel (see Fernald, 1903, Cat. Cocc. World, p. 33), *Polyocellaria* Imhof, 1900, Biol. Centbl. 20: 527; *Douglasia* MacGil-

livray (preoccupied); *Douglariella* MacGillivray (see Laing, 1922, Ent. Mo. Mag. 58: 254–255).

The primary distinguishing characters separating this genus from the other genera of the Ortheziinae have been indicated in the key already given. The genus may be diagnosed as follows:

ADULT FEMALE.—External covering, so far as developed, made up of definite and usually sharply segregated tufts of waxy secretion, these often quite long or high, more or less completely covering the body and arranged in distinct marginal and dorsal rows, the dorsal rows, when fully developed, 10 in number on each half of the body, the marginal, including that on the head and a transverse median plate at the posterior end of the body, 10 or 11 in number on each side of the body; body more or less distinctly oval, often broadly rounded posteriorly and somewhat tapering anteriorly; derm entirely membranous, or with small, dark-colored chitinized plates dorsally in varying position; antennae rather heavily chitinized, 7 to 8 segmented, the basal one or two segments not conspicuously enlarged; eyestalk varying from flat conical or tuberculate to elongate, thumblike; legs long, joint between trochanter and femur obsolete, the parts bearing a number of setae, these usually spinelike and set in definite rows, tarsal claw long, usually with denticles on the inner face, claw digitules spinelike; beak 1-segmented, with a more or less distinct suggestion of a joint near base in many species; the usual 2 pairs of thoracic spiracles present, these distinctly larger than the abdominal spiracles, the latter more or less elongate tubular, with a collar at opening, placed along margin or just within it dorsally, occurring certainly in 7 or 8 pairs, and apparently sometimes in 4 pairs, the posterior 2 on each side always placed quite close together and diagonally behind the anal ring; derm pores of the quadrilocular disk type only, these varying in size and density of chitinization, distributed over the body both dorsally and ventrally, usually in single rows between the clusters and bands of spines and in transverse rows or bands in the ventral abdominal region, rarely individually abnormal in structure, as trilocular or quinquelocular; body setae slender, set in distinct, flat, basal collars, occurring sparingly over most of the dorsum and venter but often in a distinctly developed cluster anterior to the genital opening; body spines grouped in definite clusters and bands, these, when fully developed, in 10 or 11 clusters along the margin and in 10 bands dorsally on each half of the body, in a distinct and usually broad ovisac band around the ventral margin of the abdomen, and usually in transverse rows or bands across the area inclosed by this band; dorsal bands and rarely the marginal clusters in some species more or less reduced in area, leaving exposed bare dermal areas, these usually taking on the form of longitudinal submarginal stripes, one on each side of the body; spine clusters and bands serving as bases for the tufts of secretion in the perfect insect, and the arrangement of the secretionary tufts in consequence corresponding rather closely to that of the spine clusters; ovisac band, in addition to the spines, often with disk pores along outer and inner margins and frequently through more or less of the entire width of the band; anal ring flat, more or less distinctly oval, bearing 6 relatively long, tapering setae, and, on each half, a distinct, but not always completely developed band of pores, this usually more or less evidently divided into inner and outer sections, and rarely with a small, more or less triangular, chitinized wing projecting laterad from the middle of each half of the band.

LARVA.—Body more or less distinctly oval, antennae 6- or very rarely 5-segmented; eyestalk more or less conical, in each species corresponding vaguely to the shape of this structure in the adult female; legs about as in adult female; thoracic spiracles much larger than abdominal; abdominal spiracles very difficult to locate, but, so far as placed, similar in number and shape to those of adult female; derm pores of the quadrilocular disk type; derm setae occurring occasionally; spines arranged in dorsal and marginal clusters and ventral rows, agreeing very vaguely with the condition in the adult female of the same species; anal ring with the usual pores and setae.

ADULT MALE.—Elongate, slender, abdomen with sides parallel or nearly so; thoracic lobes chitinized, remainder of body membranous with exceptions noted below; antennae 9-segmented, the 2 basal segments relatively short and stout, remainder very long, cylindrical, apical terminating in a spine as in female, hairs on outer segments rather numerous, fairly stout, of moderate length, more or less distinctly recumbent, arranged in indefinite spirals; head triangular in out-

line anteriorly; compound eyes large, each accompanied behind by a protruding ocellus; legs long and slender, the parts cylindrical, bearing numerous spines or setaelike hairs, the tarsal claws each with 2 digitules and usually 1 or 2 denticles near apex; wings rather long and slender, usually showing more or less whitish bloom on the surface, costal margin thickened, with 1 subbasal diagonal thickening or vein running nearly to margin, a more or less distinct clear line somewhat beyond and paralleling this, and rarely (*praelonga*) a second diagonal thickening intermediate in position between costal and basal diagonal veins, less distinctly developed than either and incomplete basally; abdomen terminating in a bivalved penis sheath, this curving back and down, with the tips of the valves closely appressed and forming a rounded conical apex, and on a single abdominal segment before this sheath with a transverse row of long tubular ducts, these producing the tuft of glassy threads to be seen in the living insect.

The preceding diagnosis of the adult male stage has been based on males of only four species and in consequence may not be entirely accurate for all the members of the genus. Neither thoracic nor abdominal spiracles were to be observed in any of the specimens examined, although almost certainly present. No definite group or specific characters were observed in the few species examined, and their existence seems somewhat doubtful, although a detailed study of the more minute derm structures might possibly result in the discovery of such characters.

One subgenus, which has also been regarded as a genus by some, has been erected within the genus Orthezia and appears, on the basis of the studies detailed here, to be valid. It may be separated from typical Orthezia by the key following.

KEY TO SUBGENERA OF ORTHEZIA

a. Without 3 triangular clusters of spines on the anterior portion of the dorsum along the median line, and the corresponding triangular plates of secretion also wanting; when fully developed, with 11 marginal and 10 dorsal pairs of clusters or bands of spines, and with a corresponding number of plates or tufts of secretion; eyestalk sometimes strongly asymmetrically conical, but never thumblike; tarsal claw with denticles. ORTHEZIA S. STR.

aa. With 3 more or less distinct triangular clusters of spines on the anterior portion of the dorsum along the median line, and with 3 distinct triangular plates of secretion corresponding to these; clusters of spines fully developed, forming only 10 pairs of marginal clusters instead of 11, the secretion of the perfect insect corresponding; eyestalk strongly produced, thumblike; tarsal claw without denticles ARCTORTHEZIA Cockerell.

SUBGENUS ORTHEZIA S. STR.

The characters of the subgenus Orthezia s. str. have been sufficiently indicated in the generic diagnosis of the various stages and in the subgeneric key given above.

At least one of the members of this subgenus, owing quite evidently to artificial dissemination, is at present world-wide in its distribution, although, as has already been indicated, the subgenus appears to be American in origin and development, the majority of the described species coming from the Western and Southwestern States and nearly all of the remainder from tropical or Neotropical America.

In the matter of host relationships the members of the subgenus, largely because of the diverse tastes of a few species, show so wide and varied a range that no precise connection between the subgenus as a unit and the hosts of its members is evident.

Among the members of this subgenus are present some fairly evident groups of species, and, in addition, some species which appear to stand alone. As these suggested groups can not be successfully placed in any linear arrangement and are not indicated in the key to the species which follows, or in the arrangement of the specific descriptions, it seems desirable to outline them very briefly, with the definite understanding that the order of arrangement as given in the following tabulation is not intended to show any proper phylogenetic or other sequence.

I. *insignis* Dougl. Characterized primarily by the complete absence of transverse rows or bands of spines in the ventral abdominal region and, secondarily, by the very marked reduction of the dorsal spine bands and corresponding secretion.

II. *graminis* Tins., *monticola* Ckll., and *pseudograminis*, n. sp. Characterized primarily by the occurrence of more or less distinct bare derm stripe between the dorsal and marginal clusters of spines and corresponding tufts of secretion, in combination with the occurrence of 7 pairs of abdominal spiracles, the absence of any chitinized dermal areas, the presence of a flattened conical eyestalk, and an anal ring with the inner margin of the pore bands not strongly angulate.

III. *artemisiae* Ckll., *galapagoensis* Kuw., *garryae* Ckll., *longipes* Hemp., *praelonga* Dougl., *ultima* Ckll., *varipes* Leon. Characterized primarily by the presence of an anterior, dorsal, median, chitinized derm plate extending posteriorly between the anterior marginal spine clusters, in combination with the presence of 7 pairs of abdominal spiracles, and usually a strongly conical eyestalk.

IV. *mexicana*, n. sp. Characterized primarily by the substitution, in the ventral abdominal area, of transverse rows of truncate conical tubercles for the usual transverse rows of spines, and secondarily by the absence of chitinized derm plates, the presence of 7 pairs of abdominal spiracles, complete dorsal spine bands and secretion, and numerous pores through the outer fourth of the ovisac band, but none along or through the inner margin.

V. *caudata* Ferris. Characterized primarily by the presence, in the dorsal spine bands and to some extent in the marginal clusters, of a few spines very much larger, more heavily chitinized, and much more conspicuous than the average, and secondarily by the presence of a median dorsal anterior chitinized plate as in the *garryae* group, but in combination with 8 pairs of abdominal spiracles instead of 7.

VI. *balloui*, n. sp., *minor*, n. sp., *tillandsiae*, n. sp. Characterized primarily by the apparent presence of only 4 pairs of abdominal spiracles, and secondarily, in two of the species only, by the presence of conspicuous dorsal abdominal plates in connection with the dorsal spine bands, by small size, and by subtropical distribution.

VII. *annae* Ckll., *nuda* Ferris, *nigrocincta* Ckll., *sonorensis* Ckll. Characterized primarily by the more or less marked reduction in size and shape of the spines in the collar surrounding the opening of each thoracic spiracle, and by a more or less incompletely developed anal ring, with the pore bands of this hardly angulate within and often with a more or less distinct lateral chitinized wing, in connection with the presence of 8 pairs of abdominal spiracles, and, except in *nigrocincta*, the absence of any dermal chitinization.

The species *nuda* has been somewhat doubtfully included in this group, as its structures diverge more or less distinctly from the primary characteristics indicated, and in addition it lacks some, at least, of the marginal and most of the dorsal spine clusters and secretionary tufts, while the remainder are much reduced in size.

VIII. *arenariae* Vays., *boliviana*, n. sp., *cheilanthi* Tins., *grandis* Hemp., *lasiorum* Ckll., *olivacea* Ckll., *solidaginis* Sanders, *urticae* (L.), *yashushii* Kuw. Characterized primarily by the presence of complete dorsal spine bands and secretion, 8 pairs of abdominal spiracles, 5 transverse rows of spines in the ventral abdominal region, and a usually distinctly conical eyestalk, in combination with the absence of any dermal chitinization.

Some of the species, as *cheilanthi* Tins., with slightly clavate derm spines, and *lasiorum* Ckll. and *olivacea* Ckll., with normally 7-segmented antennae, tend to diverge from the characteristic condition in this group as represented by the species *urticae* (L.).

With the exceptions indicated in the footnote, the known species of the subgenus Orthezia have been included in the following key:

KEY TO SPECIES OF THE SUBGENUS ORTHEZIA [3]

a. Ventral abdominal area, inclosed by ovisac band, without any transverse rows of spines; dorsal secretion confined to small tufts forming two complete, but narrow, longitudinal, submedian bands and exposing a wide expanse of bare derm between dorsal and marginal secretion of each side..... *insignis* Douglas.

aa. Ventral abdominal area with at least some spines in transverse rows, or, if without spines, with numerous small truncate conical tubercles in similar transverse rows, the dorsum in the latter case completely covered by secretion and with complete spine bands.

b. Dorsal spines confined to 5 small pairs of clusters along the median line on the posterior abdominal segments, secretion similarly limited, most of the dorsum completely exposed; marginal spine clusters and corresponding secretion obsolete anteriorly, ventral abdominal bands of spines poorly developed, each a single row of scattered spines..... *nuda* Ferris.

bb. Dorsal spines, at the least, forming two complete median longitudinal rows as in *insignis*, usually forming more or less complete, wide, transverse bands; marginal spine cluster pairs complete, 11 in number; ventral abdominal bands of spines usually distinctly developed, and even broad; dorsal and marginal secretion corresponding to the spine arrangement.

c. Transverse rows of spines in ventral abdominal area replaced by similar rows of small truncate conical tubercles, each heavily chitinized, but with nearly membranous cap; ovisac band with numerous disk pores through the outer fourth, but without these along or through the inner margin; dorsal spine bands and secretion very well developed; 7 pairs of abdominal spiracles..... *mexicana*, new species.

cc. Transverse bands of spines in ventral abdominal area unmodified; ovisac band varying according to the species; dorsal spines and secretion varying.

d. Some of the spines, in patches among the dorsal spine bands, conspicuously larger and more heavily chitinized than the average; dorsal spine bands and secretion complete; 8 pairs of abdominal spiracles and an anterior, median, elongate, dorsal chitinized derm patch..... *caudata* Ferris.

dd. All dorsal and marginal cluster spines approximately uniform in size, shape, and chitinization; other characters varying.

e. Spines making up spine collar surrounding opening of each thoracic spiracle very short conical, differing conspicuously in shape from remaining body spines; 8 pairs of abdominal spiracles; anal ring not sharply angulate within anteriorly and posteriorly, often with a distinctly developed chitinized wing on each side; inner spines of the 2 posterior dorsal clusters more or less distinctly reduced in size as compared with the remaining spines.

f. Dorsal spine bands on thorax and anterior abdominal segments, while transverse, terminated far from the corresponding marginal clusters, leaving a wide, bare, longitudinal derm band between dorsal and marginal spine clusters; secretion corresponding, leaving that portion of the derm exposed in perfect specimens; lateral wings of anal ring not developed or only slightly so; ovisac band inclosing only 3 transverse spine bands..... *nigrocincta* Cockerell.

ff. Dorsal spine bands continuous almost to corresponding marginal bands, although with the abdominal bands narrowed laterally, the dorsal surface, in perfect specimens, not, or only very slightly exposed; lateral wings of anal ring well developed, very evident; pore bands of anal ring incompletely developed; ovisac band inclosing 5 transverse bands of spines.

g. Larval antennae 6-segmented; inner spines of the 2 clusters just before anal ring conspicuously smaller than the remainder in the larva..... *annae* Cockerell.

gg. Larval antennae 5-segmented, the third very long and more or less constricted medially; none of the spines in the clusters just before anal ring conspicuously reduced in size in larva..... *sonorensis* Cockerell.[4]

[3] The species *americana* (Walk.), *arenariae* Vays., and *yashushii* Kuw. have been omitted from this key, as no specimens of any of the three are available for comparative study. The status of *americana* will probably never be determined with certainty, but the other two species, from the descriptions, are evidently very closely related to *urticae* (L.).

[4] No clear-cut and distinct morphological differences that will definitely separate the adult females of these two species, *annae* and *sonorensis*, have as yet been isolated; some comparative and apparent differences are indicated in the descriptions and figures of the two species.

ee. Spine collar around opening of each thoracic spiracle, if developed, made up of spines similar in shape to and, at most, only a little smaller than the remaining body spines; inner spines of those in the two posterior dorsal clusters not obviously reduced in size in comparison with the remainder; other characters varying.

h. Outer halves of the dorsal spine bands of the 4 intermediate abdominal segments displaced on each side of the body by 4 trapezoidal, heavily chitinized plates; size small, length as mounted little more than 1 mm.; apparently with only 4 pairs of abdominal spiracles.....*balloui*, new species.

hh. Body chitinization, if developed, not as described above, never interrupting the abdominal spine bands; other characters varying.

i. With 3 more or less distinctly developed, chitinized, oval plates interposed between the outer ends of the intermediate dorsal abdominal spine bands on each side; length as mounted about 1.3 mm.; apparently with only 4 pairs of abdominal spiracles.....*tillandsiae*, new species.

ii. Body chitinization, if developed, not as described above; other characters varying.

j. With a more or less elongate or oval, dorsal, chitinized derm plate extending caudad from the anterior body margin for about the depth of the anterior marginal spine band, this plate frequently obscured by the mouth parts in mounted specimens; with 7 pairs of abdominal spiracles.

k. Ovisac band inclosing 4 definite transverse spine bands, these all relatively narrow.

l. Disk pores widely scattered through the inner two-thirds of the anterior median section of the ovisac band, as well as in a band along its inner margin; no visible row of such pores along the outer (anterior) margin of this section of the band; chitinized thickening stout oval.....*variipes* Leonardi.

ll. Disk pores, at most, present only through the inner one-third of the anterior median section of the ovisac band; with a row or band of disk pores along the outer (anterior) margin of this portion.

m. Anterior median section of ovisac band relatively narrow, as little as 8 to 10 spines wide; with a single to irregularly double row of pores along outer (anterior) margin, and a band about 3 wide along and through the inner (posterior) margin; antennae slender, length about 0.9 mm.; dorsal spine bands incomplete; known only from the Galapagos Islands.....*galapagoensis* Kuwana.

mm. Anterior median section of ovisac band relatively much wider, at least 14 spines wide, other characters varying.

n. Antennae normally relatively short and with broad segments, about 0.6 mm. long; dorsal spine bands, particularly on the abdominal segments, incomplete, tapering at outer ends; anterior median section of ovisac band with a single row of disk pores along outer (anterior) margin; dorsal chitinized thickening oval.....*ultima* Cockerell.

nn. Antennae normally long and more slender, exceeding 1 mm. in length; dorsal spine bands continuous to the marginal, outer ends somewhat expanded, the individual bands on the abdomen quite narrow; anterior median section of ovisac band with a double to quadruple row of disk pores along outer (anterior) margin.

o. Anterior median section of ovisac band with only a single row of disk pores along inner (posterior) margin, but with a triple to quadruple band along outer (anterior) margin; eyestalk asymmetrically flattened conical; chitinized thickening oval.....*garryae* Cockerell.

oo. Anterior median section of ovisac band with a band of disk pores 3 or 4 wide along and through the inner (posterior) margin, and with a double to triple band along the outer (anterior) margin; eyestalk at least strongly rounded conical; chitinized thickening at most elongate triangular.

p. Eyestalk asymmetrically elongate conical; abdomen with scattered spines ventrally between the ovisac band and the anterior and posterior transverse bands of spines.....*longipes* Hempel.

pp. Eyestalk rounded conical; abdomen with only the normal 4 narrow transverse bands of spines within the ovisac band.*praelonga* Douglas.

kk. Ovisac band inclosing 5 definite transverse spine bands, these all comparatively wide; chitinized thickening on head elongate, nearly linear.....*artemisiae* Cockerell.

jj. Without dermal chitinization; ovisac band inclosing at least 5 more or less distinctly developed transverse spine bands; spiracular characters varying.

q. Apparently with only 4 pairs of abdominal spiracles; size small, length as mounted about 1.25 mm.; dorsal spine bands complete; ventral abdominal bands narrow; antennae 8-segmented..*minor*, new species.

qq. With 7 or 8 pairs of abdominal spiracles; size larger, 2 mm. or more; other characters varying.

r. With 7 pairs of abdominal spiracles; eyestalk flattened, asymmetrically conical; inner margins of pore bands of anal ring not angulate posteriorly and only indistinctly so anteriorly; antennae normally 8-segmented; with a more or less distinct bare dermal area between dorsal and marginal spine clusters and secretion tufts, at least on the thorax.

s. Exposed area of derm between marginal and dorsal spine clusters much broader than the transverse width of the corresponding dorsal spine clusters; secretion corresponding, leaving wide exposed areas between dorsal and marginal tufts and between dorsal tufts; superficial appearance similar to that of *insignis*.....*monticola* Cockerell.

ss. Exposed area of derm between marginal and dorsal spine clusters much narrower, at most not so wide as width of corresponding dorsal spine bands; dorsal secretion at most leaving only a narrow exposed band between it and marginal secretion.

t. Exposed longitudinal bands evident on anterior portion of body only, the spine bands on most of the abdominal segments complete and continuous to the corresponding marginal spine clusters; dorsal secretion more or less obviously agreeing with spine arrangement.....*pseudograminis*, new species.

tt. Exposed longitudinal bands practically complete, except at the posterior apex of the body, most of the abdominal spine bands terminating far from the corresponding marginal spine clusters; dorsal secretion more or less obviously agreeing with spine arrangement.....*graminis* Tinsley.

rr. With 8 pairs of abdominal spiracles; eyestalk usually distinctly conical rounded, neither flattened nor strongly asymmetrical; dorsal spine bands complete, broad at ends and only narrowly separated from corresponding marginal spine clusters; inner margins of pore bands of anal ring distinctly and sharply angulate anteriorly and posteriorly, or, if not so, antennae normally 7-segmented; dorsal secretion completely covering body in heavy tufts in perfect specimens.

u. Spines of the clusters, particularly dorsally, elongate, slender, slightly, but fairly distinctly, swollen at apices; dorsal and ventral abdominal spine bands very broad, the latter 6 in number; ovisac band with only a single row of scattered disk pores along inner margin.....*cheilanthi* Tinsley.

uu. Spines mostly stouter, tapering uniformly from bases to rounded apices, not clavate; dorsal and ventral spine bands narrower, or at least constricted more or less distinctly at some place in their length; usually with 5 transverse ventral abdominal spine bands; ovisac band varying but not usually as described above.

v. Antennae normally 7-segmented; size smaller, 2–2.25 mm.

w. Anal ring with chitinized lateral wings, and, beyond these, a few short conical spines on each side; anterior section of ovisac band with a row of pores 2 to 3 deep along and within its outer (anterior) margin, and with a single row of pores of the same diameter along the inner (posterior) margin; eyestalk conical-rounded.....*lasiorum* Cockerell.

ww. Anal ring without wings, conical spines on each side wanting; anterior section of ovisac band with a single row of pores along the outer (anterior) margin, and another single row, with each pore about half as large as the adjacent pores, along the inner (posterior) margin; eyestalk tuberculate, with flattened base.....*olivacea* Cockerell.

vv. Antennae normally 8-segmented; size larger, about 3 mm. or more.

x. Ovisac band with only a single row of pores, not very distinct in one species, along the inner (posterior) margin of anterior median section; spine collars around openings of thoracic spiracles evident, but not prominently developed.

y. First antennal segment at least one-fifth wider than long, the inner margin, at most, slightly curved; row of pores along inner margin of ovisac band conspicuous.....*boliviana*, new species.

yy. First antennal segment at least one-fifth longer than wide, the inner margin rather distinctly gibbous; row of pores along inner margin of ovisac band inconspicuous and in some sections apparently wanting.....*grandis* Hempel.

xx. Ovisac band with a row of pores 3 or more wide along the posterior margin or through the posterior third of the anterior section; spine collars around the thoracic spiracular openings conspicuously developed.

z. Anterior median section of ovisac band with numerous pores through its posterior half, as well as a single row along the anterior margin; eyestalk usually without traces of a lateral tubercle; fourth antennal segment usually a little shorter than the fifth.....*solidaginis* Sanders.

zz. Anterior section of ovisac band with a pore band about 3 deep only, and running along the posterior margin only, not penetrating the spine band to any marked extent; eyestalk usually with a more or less fully developed and often conspicuous lateral tubercle; fourth antennal segment usually but not always distinctly longer than the fifth.....*urticae* (Linnaeus)

ORTHEZIA AMERICANA (WALKER)

REFERENCE.—Walker, 1852, Cat. Brit. Mus. Homoptera 4: 1091.

The identity of this species is at present unknown, and from Walker's extremely brief description it can not be recognized as any one of the North American species discussed in this paper. It is highly probable that all of the older American distribution records for this species, possibly excepting the original one, refer to what we now know as *Orthezia solidaginis* Sanders. These records include Lower Canada, New York, Ohio, and Iowa. The species was originally described from "North America."

In recent correspondence Mr. Frederick Laing of the Natural History Division of the British Museum has supplied information to the effect that the type of *Orthezia americana* is neither present in the British Museum, nor, so far as is known, in any other museum in Great Britain. Since this type apparently no longer exists, and since the species can not be placed from the original description, it seems best to set it aside as a wholly unrecognizable species and to eliminate it from further consideration in connection with the genus *Orthezia*.

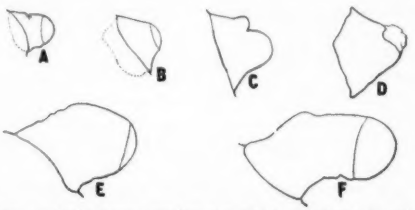


FIG. 4.—*Orthezia* spp., profiles of eyestalks, all × 120: A, *tillandsiae;* B, *ultima;* C, *urticae;* D, *varipes;* E, *cataphracta;* F, *occidentalis*

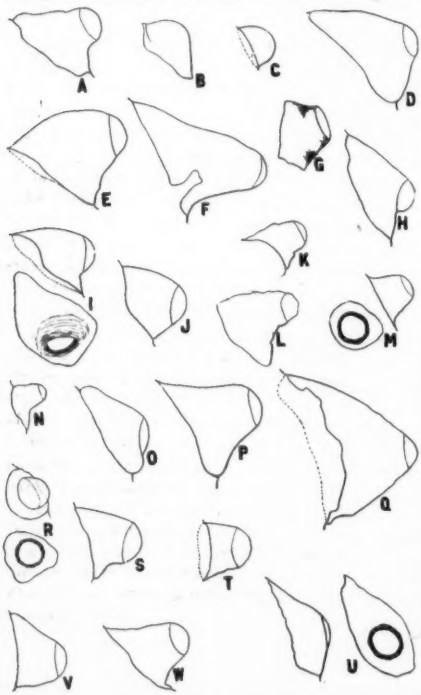


FIG. 3.—*Orthezia* spp., profiles of eyestalks, all × 120: A, *annae;* B, *artemisiae;* C, *balloui;* D, *boliviana;* E, *cheilanthi;* F, *caudata;* G, *galapagoensis;* H, *garryae;* I, *graminis;* J, *insignis;* K, *lasiorum;* L, *longipes;* M, *mexicana;* N, *minor;* O, *monticola;* P, *nigrocincta;* Q, *nuda;* R, *olivacea;* S, *praelonga;* T, *praelonga;* U, *pseudograminis;* V, *solidaginis;* W, *sonorensis*

ORTHEZIA ANNAE COCKERELL

Figs. 3, A; 5, A; 7, A; and 8; Pl. 1, A

REFERENCE.—Cockerell, 1893, Ann. and Mag. Nat. Hist. (6) 12: 403–404.

ADULT FEMALE.—Appearing approximately circular, covered dorsally with white secretion, this in a longitudinal row of fairly high tufts occupying the median third of the body, in short slightly curved tufts along the anterior and lateral margins, in considerably longer, fingerlike tufts around the posterior margin, and in low transverse ridges between the median and marginal tufts; length of ovisac variable according to development, but sometimes more than twice the length of the body, the upper surface divided into broad longitudinal plates; the body ventrally completely covered with secretion except around the insertions of the appendages; all body secretion rather fragile and easily mutilated; length as mounted on slide about

2.5 millimeters; width about 2.25 millimeters; body broad, tapering more or less distinctly anteriorly, but with the head broadly rounded; derm membranous except for a small, but fairly distinct, chitinized thickening along the outer margin of each half of the anal ring; antennae normally 8-segmented, average lengths of the segments of one in microns as follows: I, 143; II, 129; III, 161; IV, 111; V, 136; VI, 96; VII, 89; VIII, 171; eyestalk broad at base, tapering strongly to beyond middle, with apex short, cylindrical, rounded at tip; legs characteristic for the genus, tarsal claw with 2 indistinct denticles; beak about 268 microns long and 239 microns wide, 1-segmented but with a faint suggestion of a joint about one-third of the length from the base; each of the thoracic spiracles with a loose double band of very short, bluntly triangular spines around its opening, these spines differing conspicuously from the normal body type; with 8 pairs of much smaller, simple, tubular, abdominal spiracles; derm pores of the quadrilocular disk type only, varying slightly in size and appearance and occurring chiefly in the dorsal and ventral abdominal regions, most abundant along and within the inner margin of the ventral ovisac band, penetrating this in some places as much as one-third of its total width and forming a band 3 or 4 deep within the ovisac band; body spines arranged in bands and clusters approximately as shown in the figure, the median dorsal abdominal bands strongly attenuated laterally, the inner 15 to 20 spines of each of the 2 clusters immediately anterior to the anal ring conspicuously shorter than the remaining spines in these and the other bands; dorsal spines and ventral thoracic spines approximately the same in size and shape, more or less distinctly curved, tapering from base to apex; spines in the broad ovisac band and the 5 ventral rows inclosed by this band plainly, but not conspicuously, smaller and more slender than the dorsal spines, lateral and posterior portions of ovisac band more or less distinctly divided into several sections by transverse clear spaces each bearing an irregular row of disk pores; anal ring only fairly well developed as compared with some other members of the genus, with a lateral chitinized wing on each side, the chitinization anteriorly and posteriorly indistinct or wanting and the pore bands on each terminating well short of the median longitudinal line, particularly posteriorly, and not angulate within; with the usual 6 anal ring setae.

LARVA.—Stout oval, tapering slightly at each end, length when mounted 410 microns; width 311 microns; antennae 6-segmented, apical much the longest; beak relatively large, stout conical; legs not unusual, tarsal claw with 2 fairly distinct denticles; body spines both dorsally and ventrally rather abundant, arranged in transverse rows, those on the dorsal surface interrupted medially and again about half-way between the middle line and margin, those of venter apparently continuous, the inner 2 to 4 spines of each of the bands just anterior to the anal ring short triangular, distinctly differing in size and shape from the remainder of the body spines; anal ring much as in adult, except for reduction

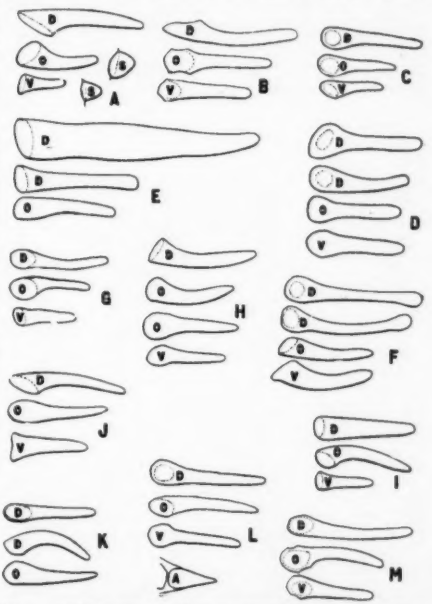


FIG. 5.—*Orthezia* spp., outlines of average body spines (d = dorsal, o = ovisac band, v = ventral abdominal, s = spiracular collar, a = near anal ring), all × 720: A, *annae;* B, *artemisiae;* C, *balloui;* D, *boliviana;* E, *caudata;* F, *cheilanthi;* G, *galapagoensis;* H, *garryae;* I, *graminis;* J, *grandis;* K, *insignis;* L, *lasiorum;* M, *longipes*

and absence of the lateral chitinized wings.

This species has been redescribed from the following material: Las Cruces, N. Mex., on *Atriplex canescens* (Chenopodiaceae), coll. T. D. A. Cockerell (type); and Arizona on Chenopodium (Chenopodiaceae), coll. C. H. T. Townsend.

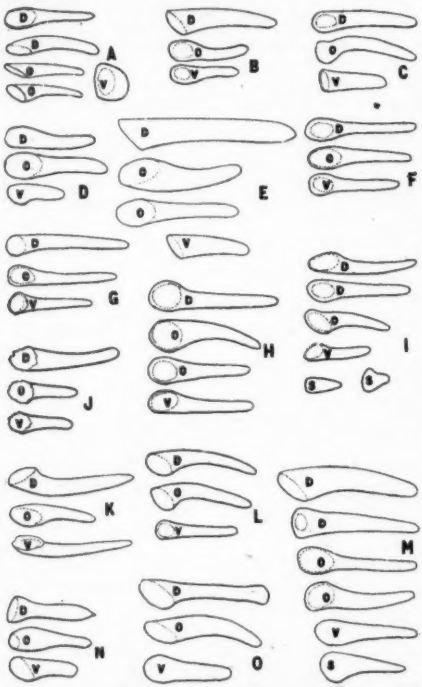


FIG. 6.—*Orthezia* spp., outlines of average body spines (letter designations as in fig. 5), all × 720: A, *mexicana;* B, *minor;* C, *monticola;* D, *nigrocincta;* E, *nuda;* F, *olivacea;* G, *praelonga;* H, *solidaginis;* I, *sonorensis;* J, *tillandsiae;* K, *varipes;* L, *ultima;* M, *urticae;* N, *cataphracta;* O, *occidentalis*

ORTHEZIA ARENARIAE VAYSSIÈRE

REFERENCE.—Vayssière, 1924, Bul. Soc. Ent. France No. 2: 28–29, fig. 1.

This species, described since the completion of the present paper, as characterized by the author, is evidently very closely related to *O. urticae* (L.). It was collected on the Djebel Tachdirt, Morocco, on *Arenaria pungens* (Caryophyllaceae). No specimens have been available for comparative study, and it has consequently not been possible to place the species precisely among those included in the key.

ORTHEZIA ARTEMISIAE COCKERELL

Figs. 3, B; 5, B; and 9; Pl. 1, B

REFERENCE.—Cockerell, 1898, Canad. Ent. 30: 19–20.

Only a single badly mutilated adult female and a few immature specimens of this species have been available for examination from the type material, and from these it has not been possible to place it with certainty. Professor Essig has very kindly supplied specimens which he has collected at Santa Paula, Calif., on *Artemisia californica* (Compositae) which appear, so far as comparison is possible, to be identical with the type, and the species has been included in the key and figured mostly on the basis of a study of Professor Essig's specimens. An extended redescription as well as the precise placing of the species within the genus must be deferred until satisfactory topotype material can be obtained. The species was originally described from Embudo, N. Mex., on Artemisia (Compositae), collected by T. D. A. Cockerell, October, 1897.

ORTHEZIA BALLOUI, NEW SPECIES

Figs. 3, C; 5, C; 7, B; and 10; Pl. 1, C

ADULT FEMALE.—Approximate length of body with all secretion, including posterior marginal tufts, 1.6 millimeters; width 1 millimeter; total length of well-developed female with ovisac 4.4 millimeters; body, except for a tiny quadrate bare spot, completely covered dorsally and ventrally with tufts of secretion, these more or less distinctly arranged in the usual marginal and lateral tufts; posterior marginal tufts of secretion very long, sometimes nearly as long as the body; average length of body as mounted 1.2 millimeters, width 1 millimeter, very broad oval, posterior apex somewhat flattened, anterior very slightly narrowed; derm membranous, except for 4 pairs of prominent, rectangular,

chitinized plates, these replacing the outer halves of the dorsal spine bands on 4 of the anterior abdominal segments, differing, in the possession of these chitinous plates, from all the previously described species of Orthezia and resembling in this respect only the species *tillandsiae*, but differing lengths of the segments of one in microns as follows: I, 82; II, 75; III, 107; IV, 75; V, 82; VI, 79; VII, 68; VIII, 154; eyestalk small, tuberculate rounded; beak conical, 1-segmented; legs characteristic for the genus, rather slender, tarsal claw with 2 comparatively prominent denticles on the inner

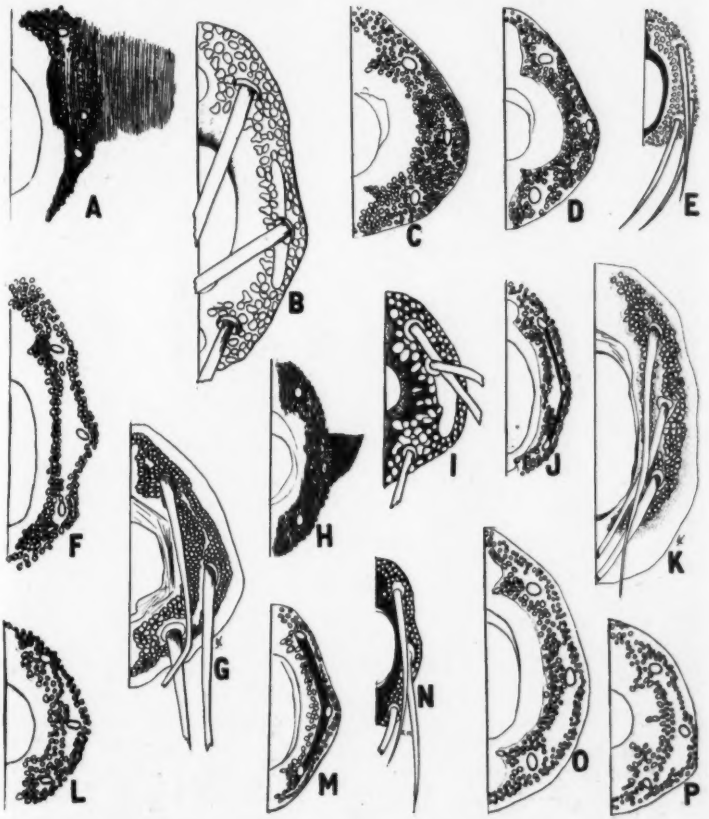
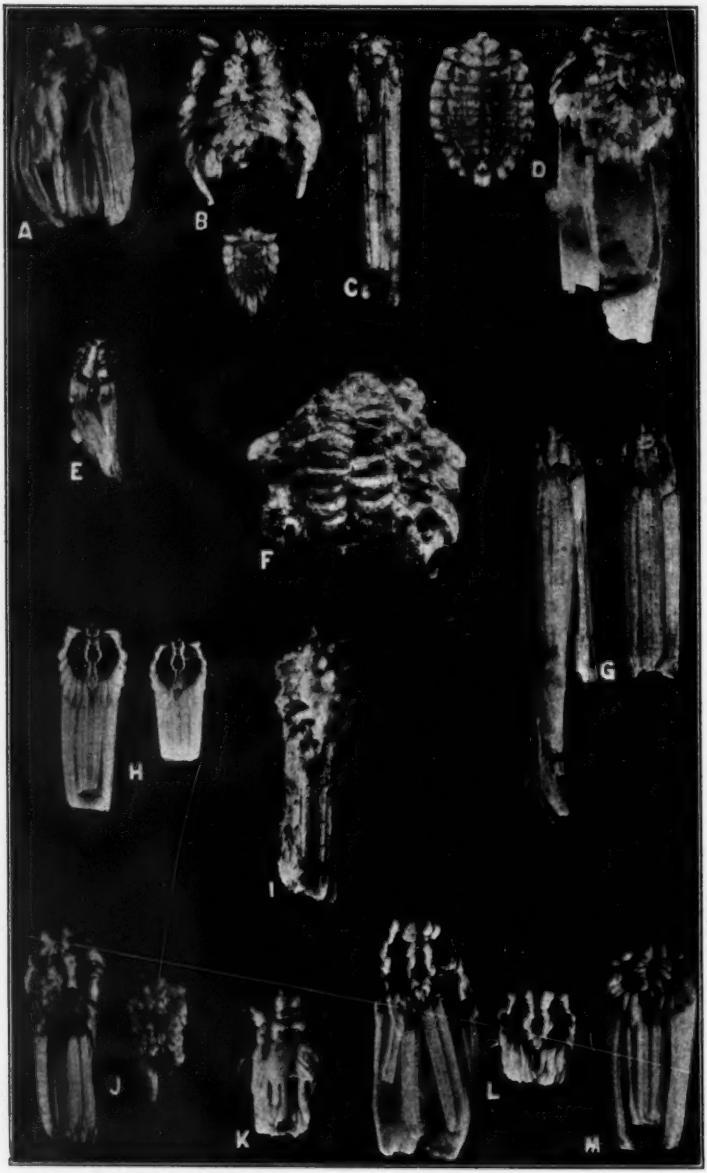


FIG. 7.—*Orthezia* spp., right half of anal ring of certain species, all × 217, except B and I, which are × 510: A, *annae;* B, *ballouí;* C, *boliviana;* D, *cheilanthi;* E, *galapagoensis;* F, *garryae;* G, *grandis;* H, *lasiorum;* I, *minor;* J, *nigrocincta;* K, *nuda;* L, *olivacea;* M, *praelonga;* N, *tillandsiae;* O, *urticae;* P, *cataphracta*

obviously from the latter in that the plates are much more conspicuous, much better developed, and interrupt the dorsal spine bands instead of merely occupying a position between the outer sections of such bands; antennae normally 8-segmented, the face; thoracic spiracles characteristic for the genus, each opening in a spine cluster but without definite spine collar around the opening; with, so far as can be determined, 4 pairs of long tubular abdominal spiracles; derm pores of the usual quadrilocular disk



Scale Insects of the Subfamily Orthezlinae Plate I

A, *Orthezia annae*, adult female; B, *O. artemisiae*, mutilated adult and immature females; C, *O. balloui*, adult female, secretion mutilated; D, *O. cheilanthi*, mutilated adult and preadult females; E, *O. galapagoensis*, adult female, secretion mutilated; F, *O. grandis*, adult female, ovisac wanting; G, *O. graminis*, adult females; H, *O. insignis*, adult females (photo by J. G. Sanders); I, *O. longipes*, adult female, attacked by fungus; J, *O. mexicana*, adult females, secretion badly mutilated; K, *O. minor*, adult female; L, *O. monticola*, adult females, secretion slightly mutilated; M, *O. nigrocincta*, adult female

type, occurring both dorsally and ventrally, most abundant ventrally in the posterior abdominal region; derm with occasional setae both dorsally and ventrally, these most abundant ventrally in a cluster just anterior to the genital opening; derm with the usual 11 marginal and 10 dorsal clusters of spines, the dorsal spine bands wide, continuous from the median line to the marginal clusters, except for the interruptions formed by the chitinized plates on the abdomen, as already described; ventral ovisac band wide, made up of closely crowded spines with a few disk pores along the anterior margin, the band inclosing 3 loose transverse rows of spines, the anterior several spines wide, the 2 posterior little more than irregular single rows, all continuous and reaching nearly to the ovisac band at each end; anal ring elongate oval, each half with the usual inner and outer pore bands with the inner margin distinctly angulate anteriorly and posteriorly, and the bands of each half joined anteriorly but more or less distinctly separated behind; with the usual 6 anal ring setae.

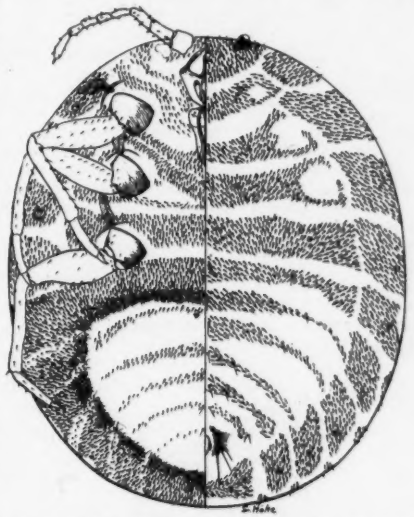


FIG. 8.—*Orthezia annae:* Adult female, body, dorsal and ventral; × about 31.

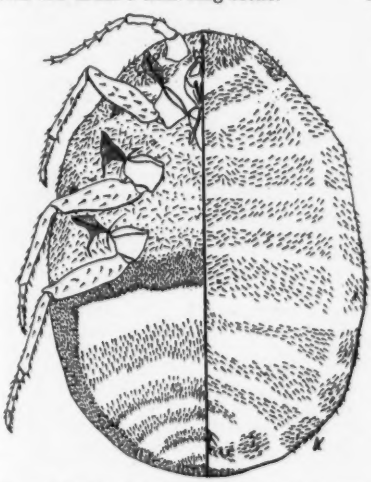


FIG. 9.—*Orthezia artemisiae:* Adult female, body, dorsal and ventral; × about 31.

This species has been described from five mounted and two or three unmounted adult females recently forwarded for determination by C. H. Ballou, Officina de Sanidad Vegetal, Havana, Cuba. The specimens were collected at Pico Turquino, Oriente Province, Cuba, on *Palicourea crocea* (Rubiaceae), July 22, 1922, by C. H. Ballou and S. C. Bruner under No. 364.

The types are in the U. S. National Collection of Coccidae.

ORTHEZIA BOLIVIANA, NEW SPECIES

FIGS. 3, D; 5, D; 7, C; and 11

ADULT FEMALE.—Stout oval, length with secretion little more than 3 millimeters, width about 2.5 millimeters, very slightly narrowed anteriorly; ovisac short, average length about 2.5 millimeters, presumably completely covered both dorsally and ventrally with white secretionary plates, and these, in a portion of the dorsal area at least, forming overlapping scalelike plates similar to those of *cheilanthi*, but this secretion much too incomplete for description in the specimens available for examination; length as mounted about 3 millimeters, width 2.5 millimeters, broad oval, very slightly narrowed anteriorly; derm membran-

ous; antennae normally 8-segmented, rather short and stout, lengths of the segments of one in microns as follows: I, 107; II, 100; III, 85; IV, 61; V, 61; VI, 57; VII, 60; VIII, 168; spine, 25; eyestalk heavily chitinized, asymmetrically flat conical, apex rounded; legs characteristic for the genus, inner face of tarsal claw usually with 2 tiny denticles; beak rather long triangular, 1-segmented, with a faint suggestion of a joint near the base; thoracic spiracles characteristic for the genus, each opening into a pore cluster, each opening surrounded by a fairly distinct collar of spines; with 8 pairs of tubular abdominal spiracles; derm pores of the usual quadrilocular disk type, occurring both dorsally and ventrally, those of the dorsum usually more heavily chitinized than the ventral pores; with

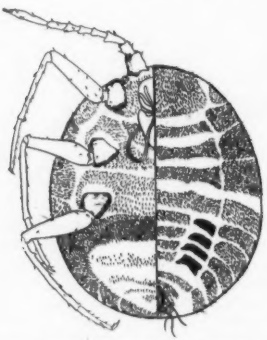


FIG. 10.—*Orthezia balloui:* Adult female, body, dorsal and ventral; × about 31

occasional setae both dorsally and ventrally, these most abundant in a transverse cluster anterior to the genital opening ventrally; derm spines arranged in the usual 11 marginal and 10 dorsal clusters, the dorsal bands transverse, broad, extending close to the corresponding marginal clusters; ventral ovisac band wide, made up of numerous spines, these more crowded toward the inner margin, and along the latter a single, irregular row, sometimes more or less interrupted, of disk pores; band inclosing 5 transverse rows of spines, these terminating laterally before attaining the ovisac band, and with the anterior several spines wide; anal ring short oval, with the pore bands on each half very broad and the inner and outer halves completely joined to form a single band, except, at most, for a very short distance posterior to the insertion of the middle seta, each band joined to the other at the ends and angulate within anteriorly and posteriorly as in *urticae*.

LARVA.—Not displaying any obvious peculiarities; antennæ 6-segmented; anal ring much as in adult except for reduction; spines arranged in transverse segmental rows; dorsal spines crowded into marginal and submedian clusters on each half of the body.

This species has been described from five mounted and a few unmounted adult females and three mounted larvae, all collected at Guaqui, Bolivia, among roots of "Vareta," by W. R. Allen, March 7, 1919. The specimens were received for study from Prof. J. G. Needham of Cornell University, Ithaca, N. Y.

The types are in the U. S. National Collection of Coccidae.

ORTHEZIA CAUDATA FERRIS

Figs. 3, F; 5, E; and 12

REFERENCE.—Ferris, 1921, Stanf. Univ. Pubs., Biol. Sci. 1: 71, fig. 1.

ADULT FEMALE.—No specimens available for description of external apperance (see reference cited for this); length, as mounted, 3 millimeters, width about 2.75 millimeters, broad oval, tapering somewhat anteriorly; derm membranous except for appendages and faint linear longitudinal median stripe running back from the anterior margin on the dorsal surface for a little more than the width of the anterior marginal spine cluster; antennae normally 8-segmented, lengths in microns for one as follows: I, 178; II, 143; III, 186; IV, 146; V, 161; VI, 161; VII, 143; VIII, 232; inner face of first segment strongly bulging; eyestalk elongate conical, heavily chitinized; legs characteristic for the genus, elongate, rather slender; tarsal claw with 3 to 4 slight denticles on its inner face; beak elongate conical, 1-segmented, with a suggestion of a joint about one-third of its length from base; thoracic spiracles not unusual, external opening surrounded by a very loose circle of quadrilocular disk pores but without a distinct collar of spines; with 8 pairs of long tubular abdominal spiracles; derm pores of the usual quadrilocular disk type only, these fairly well chitinized, apparently vary-

ing only slightly in size and quite abundant as compared with many other species of the genus, occurring both dorsally and ventrally, particularly in the posterior portion of the area enclosed by the ovisac band, occurring here in crowded transverse bands of less heavily chitinized, somewhat smaller pores; normal body spines arranged in groups about as shown in figure, these present in 11 marginal clusters including the anterior and 10 dorsal transverse bands on each half of the body; conspicuously stouter and heavier body spines interspersed through these clusters, about as shown in figure, but the arrangement apparently more or less variable; ovisac band fairly broad, made up of numerous spines, with a considerable number of disk pores scattered through the whole breadth of the band, but more numerous on the anterior and posterior margins, indistinctly interrupted laterally and posteriorly by narrow clear strips; ovisac band inclosing, besides the numerous pores already mentioned, apparently 4 fairly distinct transverse bands of rather elongate, slender spines; anal ring well developed, characteristic for the genus, with the inner margin of the band of numerous pores on each half distinctly but not conspicuously angulate; ring normally bearing 6 fairly long setae.

This species has been redescribed from a single adult female from Todos Santos Lower California, on *Encelia palmeri* (Compositae) collected by G. F. Ferris, August, 1917 (paratype). There are no additional published records of its occurrence.

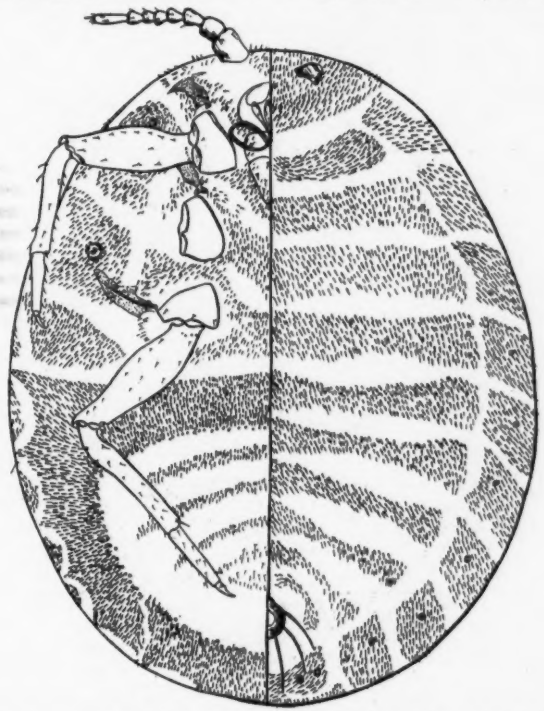


FIG. 11.—*Orthezia boliciana*: Adult female, body, dorsal and ventral; × about 31

ORTHEZIA CHEILANTHI TINSLEY

Figs. 3, E; 5, F; 7, D; and 13; Pl. 1, D

REFERENCE.—Tinsley, 1898, Canad. Ent. 30: 12–13, fig. 1.

ADULT FEMALE.—Length of dried specimens with secretion about 3.5 millimeters, width approximately the

same; ovisac about 4 to 4.5 millimeters long, nearly as wide as the body, narrowed near the posterior apex, composed of a solid dorsal plate with lateral keels and longitudinal striations, a broad, curved, transversely strongly rounded, nearly smooth ventral plate and, between these two, 3 more or less distinct elongate ribs; body secretion dorsally arranged in the usual marginal plates, these rather short anteriorly but becoming longer, more strongly curved, flattened and somewhat pointed toward the posterior end of the body, the penultimate pair from one and a half to two times the length of any of the others; secretion covering the disk of the dorsum, instead of being arranged in the usual 10 pairs of definite and distinct plates, with only the inner portion of each of these plates definitely formed, the remainder of the secretion made up of a number of overlapping scalelike plates, producing an appearance rather different from that usually found in the genus; length of body as mounted normally about 3.5 millimeters, width about 2.5 to 3 millimeters, nearly oval, somewhat pointed anteriorly; derm membranous; antennæ normally 8-segmented, lengths of segments of one in microns as follows: I, 161; II, 100; III, 150; IV, 93; V, 89; VI, 85; VII, 89; VIII, 186; eyestalk stout, rounded conical, somewhat curved; legs apparently not unusual for the genus, although no complete examples available for examination; beak stout conical, 1-segmented, without indication of a further division; thoracic spiracles normal, the external opening of each surrounded by a collar of spines differing distinctly but not conspicuously in shape and size from the remaining body spines; with 8 pairs of long tubular, submarginal abdominal spiracles; derm pores of the usual quadrilocular

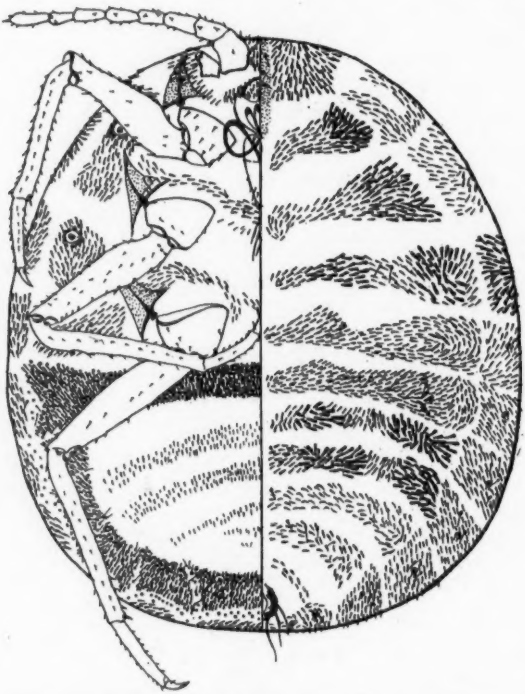


FIG. 12.—*Orthezia caudata:* Adult female, body, dorsal and ventral; × about 31

disk type only, occurring both dorsally and ventrally, most abundant ventrally in the posterior portion of the area inclosed by the ovisac band, only rarely heavily chitinized and nearly always with a distinctly wider marginal area around the 4 loculi than is usual for the genus; body spines relatively

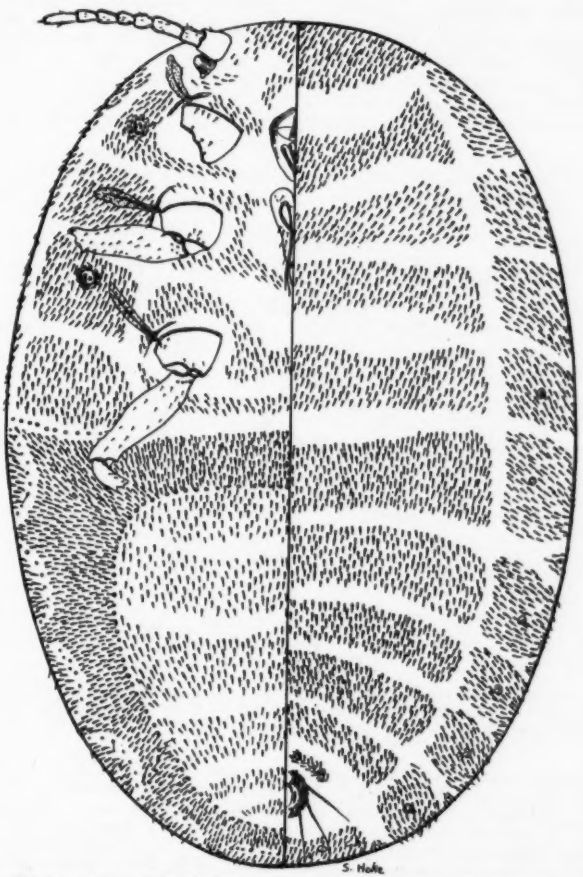


FIG. 13.—*Orthezia cheilanthi:* Adult female, body, dorsal and ventral; × about 31

elongate, slender, normally only slightly tapering and with apices slightly but distinctly swollen in contrast to the usual rather strongly tapering, apically rounded or pointed spines occurring in most species in the genus; spines arranged in the usual 11 marginal and 10 submarginal clusters on each half dorsally but, so far as can be determined, not broken up into small groups or clusters to correspond precisely with the scalelike plates of secretion; ovisac band rather broad, interrupted only once in each half, composed only of spines, with a single row of disk pores along its inner margin, inclosing, so far as can be determined, 6 broad transverse bands of rather loosely grouped spines, these, in combination, almost completely filling the space surrounded by the ovisac band; anal ring apparently not unusual for the genus, with the usual 6 rather long tapering setæ, the inner margin of the pore band on each half sharply angulate anteriorly and posteriorly, the pore bands sometimes united or nearly so at their apices.

This species has been redescribed from the following material: Organ Mts., N. Mex., on *Cheilanthes fendleri* (Polypodiaceae, Order Filicales), collected by J. D. Tinsley, August, 1897 (type). There appears to be no subsequent record of its continued existence or wider distribution.

ORTHEZIA EDWARDSII ASHMEAD

REFERENCE.—Ashmead, 1888, Canad. Ent. 20: 203–204.

Only the male of this species has been described and an examination of the description shows clearly that the species can not be assigned to the genus Orthezia, but, as was suggested by Professor Cockerell, it is probably the male of a pseudococcine form, and very likely the male of a species of Puto or Ceroputo. The species was described from California.

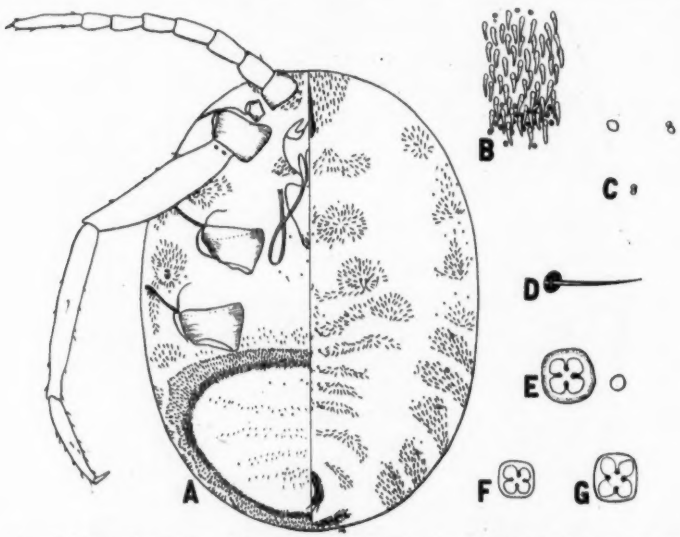


FIG. 14.—*Orthezia galapagoensis*, adult female: A, Body, dorsal and ventral, × about 55; B, section through median area of anterior portion of ovisac band, × 220; C, simple derm pores, × 500; D, body seta, × 500; E, dorsal quadrilocular pore, accompanied by simple pore, × 1,500; F, ventral quadrilocular disk pore, × 1,500; G, disk pore from ovisac band, × 1,500

ORTHEZIA GALAPAGOENSIS KUWANA

Figs. 3, G; 5, G; 7, E; and 14; Pl. 1, E

REFERENCE.—Kuwana, 1902, Jour. N. Y. Ent. Soc. 10: 28–29.

ADULT FEMALE.—External appearance most nearly resembling that of *graminis* and *nigrocincta*, in that there is a distinct exposed longitudinal derm band on the dorsum on each side between the median and marginal tufts; body of female, as mounted on slide, about 1.5 millimeters long by 1 millimeter wide; derm membranous throughout except for median longitudinal anterior chitinized stripe extending posteriorly from the front margin of the head and varying somewhat in extent and conspicuousness; antennae normally 8-segmented, measurements of segments of one in microns as follows: I, 70; II, 79; III, 100; IV, 107; V, 89; VI, 93; VII, 82; VIII, 186; spine, 25; eyestalk stout conical, apex more or less distinctly flattened; legs not unusual for the genus, but long in proportion to the size of the body, in this particular resembling the proportions in *insignis* and *praelonga*, tarsal claw slender, nearly straight, inner face with 2 or 3 indistinct denticles on apical half; beak stout conical, apex rounded, without traces of segmentation at any point, with the usual 2 pairs of thoracic spiracles, the opening of each of these within a cluster of spines, but surrounded neither by a distinct spine collar nor by differentiated spines of any kind; with 7 pairs of long tubular abdominal spiracles; derm pores of the quadrilocular disk type only, these scattered sparingly over the body, most abundant in the inner portion of the ovisac band, each of

those on dorsum, at least, usually accompanied by one or two tiny clear circles; body spines of the usual sort, and arranged in the usual 10 dorsal and 11 marginal clusters, approximately as shown in figure; dorsal spines longest, straight or slightly curved, ventral abdominal spines the shortest and stoutest; body with setae occasionally both dorsally and ventrally, these longer and larger dorsally; ovisac band rather narrow, made up as usual of crowded spines, a single row of scattered disk pores about 3 to 4 deep along and within the inner margin, band inclosing 4 transverse rows of scattered spines; anal ring not unusual for the genus, the inner margin of the pore bands indistinctly angulate anteriorly but without such angulation behind, ring bearing the usual 6 setae; posterior portion of the ventral abdominal area with some small clear disks, possibly ventral cicatrices, in addition to a number of the usual disk pores.

This species has been redescribed from two specimens on "*Scalesia microcephala* 254, Tagus Cape Albemarle I. Type L. 375–S. 1 Entomological Lab. Stanford University S. I. K. 1901" remounted and very kindly loaned for study by Prof. G. F. Ferris of Stanford University. Additional specimens, recently reported on by the writer, collected by Dr. Wm. Beebe on *Heliotropinum parviflorum* (Borraginaceae) and on *Bursara graveolens* (Burseraceae) in the Galapagos Islands, have also been examined.

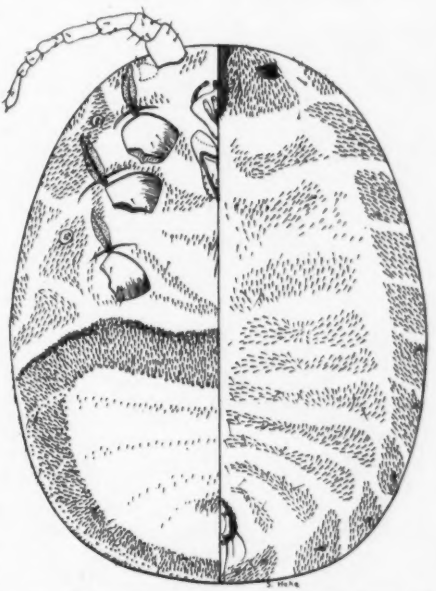


FIG. 15.—*Orthezia garryae:* Adult female, body, dorsal and ventral; × about 31

ORTHEZIA GARRYAE COCKERELL

Figs. 3, H; 5, H; 7, F; and 15

REFERENCE.—Cockerell, 1898, Ann. and Mag. Nat. Hist. (7) 2: 401–402.

ADULT FEMALE.—No specimens available for redescription of external appearance and the following quoted from the original description: "Length about 2½ mm., with ovisac about 7 mm. Body pale pea green; ovisac strongly curved upwards, composed of ribbon-like longitudinal bands, which are contiguous, but little or not coherent; lateral dorsal area only clothed with thin meal; middle of back with a double crest of long erect white lamellae; sides with long thick curling white lamellae, the two at the beginning of the ovisac on each side very long and curving downward over the side of the ovisac; caudal lamellae very short." Length of body as mounted 2.5 mm., width about 2 mm.; broadly rounded posteriorly, tapering somewhat anteriorly; derm membranous, except for a fairly distinct dorsal median, longitudinal, somewhat chitinized band extending in from the anterior margin about the width of the anterior spine cluster; antennae normally 8-segmented, lengths of segments of one in microns as follows: I, 140; II, 125; III, 186; IV, 168; V, 143; VI, 104; VII, 96; VIII, 207; spine, 25; basal portion of eyestalk flat conical, with an angular, protruding, hemispherical, apical cap; legs not unusual for the genus, the spines on all the segments relatively more elongate and slender than in most of the species of the genus, tarsal claw with 2 or 3 fairly distinct denticles on the inner face; beak stout conical, 1–segmented, without indication of any subdivisions; thoracic spiracles characteristic for the genus, each surrounded by a spine cluster, but without a distinctly developed spine collar; with 7 pairs of long tubular, abdominal spiracles; derm pores of the usual quadrilocular disk type only, these present both dorsally and ventrally, but much more

numerous over the ventral surface, most of these with rather wide outer walls surrounding the loculi, the maximum and minimum diameters varying to a marked degree, the largest nearly twice the size of the smallest; body with setae scattered sparingly over most of the surface, but with a distinct and rather prominent transverse cluster of slender setae occurring ventrally just anterior to the genital opening; spines arranged in the usual 11 marginal and 10 dorsal clusters on each half of the body about as shown in figure, the dorsal bands narrowed medially or otherwise modified; ovisac band broad anteriorly, somewhat narrowed posteriorly, made up of spines, with a band of disk pores 2 to 3 deep along its anterior and outer margins, and a single irregular row along the inner margin of the anterior section, this broadening to an irregular row 2 or 3 deep along the inner margins of the lateral and posterior sections, band interrupted laterally and posteriorly by transverse clear areas, and inclosing, besides the disk pores already mentioned, 4 narrow transverse bands of scattered spines extending almost to the ovisac band at each end; anal ring elongate oval, the outer margin sinuate opposite the insertions of the 6 ring setae, with numerous pores, the inner margin of pore row distinctly but not prominently angulate anteriorly and posteriorly.

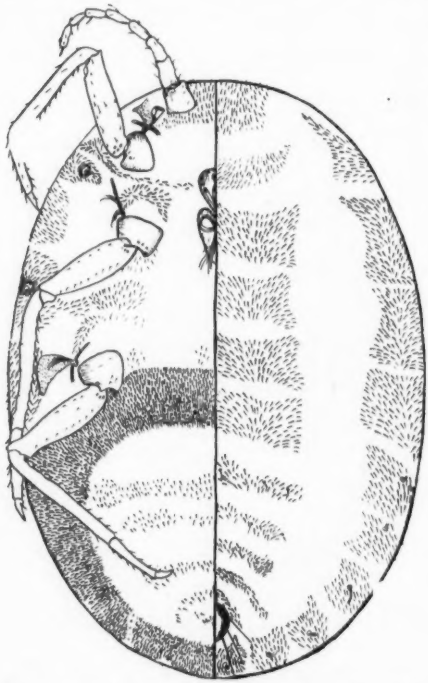


FIG. 16.—*Orthezia graminis*: Adult female, body, dorsal and ventral; × about 31

This species has been redescribed from the following material: Dripping Springs, Organ Mountains, N. Mex., on *Garrya wrightii* (Cornaceae), coll. T. D. A. Cockerell (type). Only one additional record has been made, the species having been identified by Cockerell from material collected at Grand Canyon, Ariz., on Fendlera (Hydrangeaceae) by E. Bethel.

ORTHEZIA GRAMINIS TINSLEY

Figs. 3, I; 5, I; and 16; Pl. 1, G

REFERENCE.—Tinsley, 1898, Canad. Ent. 30: 13–14, fig. 2.

ADULT FEMALE.—Average length of body of dried specimens about 2 millimeters, width somewhat less; broad oval, tapering somewhat anteriorly, ovisac, when fully developed, much longer than the body, attaining a length of as much as 10 millimeters; dorsally with marginal and median plates or tufts of secretion, leaving an intermediate submarginal bare band running the full length of the body and interrupted by the dorsal plates only at the posterior end of the body; all secretions fragile, lateral tufts smaller, fingerlike, posterior ones flattened and curved backwards over the ovisac, middle dorsal tufts plainly paired, closely crowded and standing nearly erect and fairly high; ovisac more or less distinctly ribbed and striate dorsally; anterior pair of median plates directed forward and appearing much larger than any of the others; body, as mounted, more or less distinctly oval, usually tapering somewhat anteriorly, length averaging a little more than 2.5 millimeters, width averaging about 2 millimeters, derm membranous except for a slight chitinized thickening on each side of the genital opening; antennae normally 8-segmented, measurements of one in microns as follows: I, 118; II, 107; III, 125; IV, 107; V, 107; VI, 96; VII, 89; VIII, 143; spine, 18; eyestalk rather flat conical, with

the eye slightly protruding; legs not unusual for the genus, fairly slender, tarsal claw with 1 or 2 indistinct denticles on the inner face; beak short, stout conical, 1-segmented, without definite indication of any subdivision; thoracic spiracles entirely characteristic for the genus, each surrounded by a spine cluster and with a fairly distinct band of spines about its opening; with 7 pairs of long tubular abdominal spiracles; derm pores of the quadrilocular disk type only, these very distinctly present in two sizes, the smaller hardly more than half the size of the larger; with a few slender setae scattered over the body surface, these more abundant in the ventral area enclosed by the ovisac band; derm spines occurring in the usual 11 marginal and 10 dorsal clusters, with a distinct and broad clear area in the derm widely separating corresponding marginal and dorsal bands; ovisac band broad and heavy, made up of numerous spines and with a considerable number of pores scattered through the inner one-half to two-thirds of the band; band inclosing 5 transverse bands of scattered spines, each band of moderate width and extending well towards but not reaching the inner margin of the ovisac band; anal ring rather elongate oval, the pore bands on each half relatively narrow, not very heavily chitinized, usually united or nearly so anteriorly, but more widely separated posteriorly, the inner margins not sharply angulate anteriorly and posteriorly as in many species of the genus, with the usual 6 tapering setae.

This species has been redescribed from the following material: Mesilla Park, N. Mex., on grass (Gramineae), coll. J. D. Tinsley, September 26–7, 1897 (type); Dona Ana, N. Mex., on grass, coll. C. H. T. Townsend, September 26, 1897. Published records for the species include Marshall Co., Kans., on *Solidago* sp. (Compositae), and Los Angeles Co., Calif., on a perennial grass. A number of specimens previously determined as *graminis* are included under *pseudograminis* subsequently described as new.

ORTHIZIA GRANDIS HEMPEL

Figs. 5, J, and 7, G; Pl. 1,F

REFERENCE.—Hempel, 1920 (received 1921), Rev. Mus. Paulista 12: 342–343, 365–367.

Through the courtesy of the describer of this species, and of the Museo Paulista, the present writer has been permitted to examine specimens from the type material, and it has been included in the key on the basis of this examination. The mount obtained from the single adult female received was unfortunately not sufficiently satisfactory to permit the preparation of a figure showing the spine groups or to permit an adequate redescription comparable to those given for other species discussed in this paper.

This species was collected near Sao Paulo, Brazil, on *Guadua distorta* Rupr. ? (Gramineae).

ORTHEZIA INSIGNIS DOUGLAS

Figs. 3, J; 5, K; 17, and 18; Pl. 1, H

REFERENCE.—Douglas, 1887, Ent. Mo. Mag. 24:95–101, 165–171, illus.

SYNONYM.—*Orthezia nacra* Buckton (see Fernald, 1903, Cat. Cocc. World, p. 34).

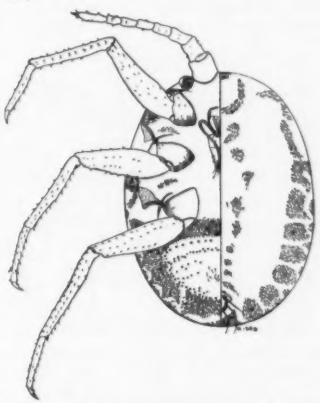


FIG. 17.—*Orthezia insignis:* Adult female, body, dorsal and ventral; × about 31

ADULT FEMALE.—Body almost uniformly oval; secretion very much reduced, occurring laterally in the usual fashion, except that the anterior plates are much reduced in size and the posterior marginal plates rather elongate and slender, but present dorsally only as 2 median longitudinal rows of small tufts, closely approximated anteriorly and posteriorly, but somewhat separated about the middle of the body, leaving a broad, dull-green bare area running the full length of the body on each side between the marginal and median rows, and a much smaller, oval, similarly bare area medially; apices of anterior dorsal plates also separated, leaving another median bare area at the apex of the head; ovisac variable in length, somewhat narrowed posteriorly, more or less distinctly ribbed dorsally and sometimes nearly twice the

length of the body; body of female, as mounted, somewhat variable in size, but in well developed specimens averaging about 1.5 millimeter in length by 1 to 1.25 millimeter in width; derm membranous; antennae normally 8-segmented, measurements of the segments of one in microns as follows: I, 100; II, 68; III, 82; IV, 79; V, 79; VI, 71; VII, 68; VIII, 150; eyestalk short and stout conical, almost tuberculate; legs relatively large and long as compared to the size of the body, and to a similar relation in other species in the genus, otherwise characteristic for the genus, tarsal claw with 1 or, more frequently, 2 small denticles on the inner face, spines on legs rather slender; beak elongate conical, 1-segmented, sometimes with an indefinite indication of a joint visible near base; thoracic spiracles characteristic for the genus, external opening of each surrounded by a spine cluster including some smaller spines close to the opening, but without a distinctly developed spine collar; with 7 pairs of simple, tubular, abdominal spiracles; derm pores of the usual quadrilocular disk type only, these occurring both dorsally and ventrally but much more abundant ventrally within the area inclosed by the ovisac band, varying noticeably in chitinization and to some extent in size, the more heavily chitinized ones with a depth nearly as great as their diameter; derm with setae scattered over the surface both dorsally and ventrally, most numerous in loose clusters anterior to the genital opening ventrally; arrangement of the body spine clusters corresponding to the patches of secretion showing on perfect specimens, and about as shown in figure; ovisac band broad, made up of spines with some quadrilocular disk pores along the outer margin and others paralleling but not adjacent to the inner margin; area enclosed by this band without any transverse rows of spines, in this respect differing from all the other species of the genus; anal ring oval to elongate oval, the pore band on each half distinctly but not prominently angulate anteriorly and posteriorly on its inner margin and normally continuous with the opposite band at the anterior and posterior ends of the ring, this again differing from the condition among most of the species in the genus; with the usual 6 anal ring setae.

This species has been reported from or is represented in the collections examined from the following localities:

Algeria, Antigua, Barbados, Bermuda, Brazil, British Guiana, Canal Zone, Ceylon, China, Costa Rica, Cuba, Dominica, Ecuador, England (in greenhouses), France, Guatemala, Hawaii, Italy, Jamaica, Java, Madeira, Mauritius, Mexico, Montserrat, Panama, Peru, Porto Rico, Portuguese East Africa, Saint Kitts, Saint Lucia, Saint Thomas (Virgin Islands), Saint Vincent, San Thomé (Africa), Santo Domingo, Straits Settlements, United States (in greenhouses), including California, Connecticut, District of Columbia, Illinois, Indiana, Massachusetts, New Jersey, New York, Ohio, Pennsylvania, and Virginia.

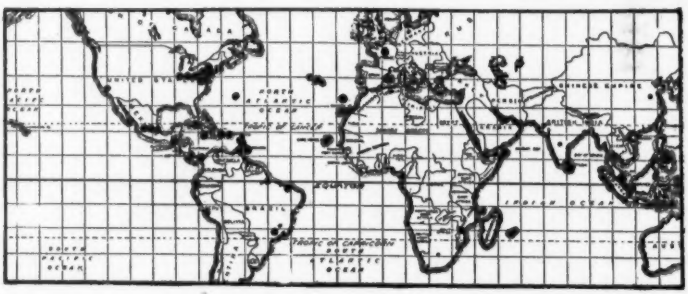


FIG. 18.—*Orthezia insignis:* Map showing actual known distribution. Large dots show records based on specimens actually examined; small dots show records based on published reports of occurrence

Host records on the same basis as distribution, that is, including both published records and those based on identifications of material, are as follows:

Abutilon (Malvaceae), Achillea (Compositae), Achyranthes (Amarantaceae), Ageratum (Compositae), Aloysia (Verbenaceae), Atalantia (Rutaceae), Barleria (Acanthaceae), Bignonia (Bignoniaceae), Capsicum (Solanaceae), Catalpa (Bignoniaceae), Cestrum (Solanaceae), Chionanthus (Oleaceae), Chrysanthemum (Compositae), Cineraria (Compositae),

Citrus (Ruraceae), Clerodendron (Verbenaceae), Clitoria (Leguminosae), Coffea (Rubiaceae), Coleus (Labiatae), Conoclinium (Compositae), Crossandra (Acanthaceae), Cuphea (Myrtaceae), Duranta (Verbenaceae), Eranthemum (Acanthaceae), Eupatorium (Compositae), Euphorbia (Euphorbiaceae), Fragaria (Rosaceae), Gardenia (Rubiaceae), Habrothamnus (Solanaceae), Ipomoea (Convolvulaceae), Iresine (Amarantaceae), Ixora (Rubiaceae), Jacaranda (Bignoniaceae), Justicia (Acanthaceae, Lantana (Verbenaceae), Libonia (Acanthaceae), Ligustrum (Oleaceae), Lycopersicum, (Solanaceae), Magnettia (Rubiaceae), Mentha (Labiatae), Meyeria (Acanthaceae), Mysotis (Boraginaceae), Oxalis (Geraniaceae), Pelargonium (Geraniaceae), Peristrophe (Acanthaceae), Pilea (Urticaceae), Rosa (Rosaceae), Rubiaceae, Saccharum (Gramineae), Salvia (Labiatae), Scutellaria (Labiatae), Solanum (Solanaceae), Stevia (Compositae), Strobilanthes (Acanthaceae), Theae (Ternstromiaceae), Thunbergia (Acanthaceae), Verbena (Verbenaceae), Veronia (Compositae), Viola (Violaceae).

ORTHEZIA LASIORUM COCKERELL

Figs. 3, K; 5, L; 7, H; and 19

REFERENCE.—Cockerell, 1901, Canad. Ent. 33: 209.

ADULT FEMALE.—No specimens available for description of external appearance, the following therefore copied from the original description "about 2 mm. long; pale orange; ovisac (in specimens seen) not very long; two very long median white caudal lamellæ, about two-thirds length of body, curving over ovisac, but not attached to it. Dorsum covered with waxy secretion, but it is so easily deciduous that I have never found an adult with it sufficiently in place to describe," body membranous except for a definite chitinous patch attached to each side of the anal ring as in *annae;* antennae normally 7-segmented, lengths of one in microns as follows: I, 107; II, 71; III, 107; IV, 71; V, 50; VI, 47; VII, 132; spine, 21; eyestalk conical, protruding, slightly curved; legs mutilated, structure uncertain; beak stout conical, 1-segmented, with an indistinct suggestion of a joint near base; thoracic spiracles set in a spine cluster and with a fairly distinct loose collar of spines around the opening of each; with 8 pairs of long tubular abdominal spiracles; derm pores of the quadrilocular disk type only, these occurring both dorsally and ventrally, usually in more or less distinct, but very scattered transverse rows, most abundant ventrally in the area inclosed by the ovisac band, fairly well chitinized, varying only slightly in size; body with slender setae occurring occasionally both dorsally and ventrally, most abundant, but not distinctly clustered, in the area inclosed by the ovisac band; derm spines arranged in the usual dorsal and lateral marginal clusters about as shown in figure, the dorsal bands larger and continuous to the marginal clusters; ovisac band broad, made up of spines, with an irregular single row of disk pores along the inner margin, and, anteriorly at least, an irregular double or triple row of similar pores along and

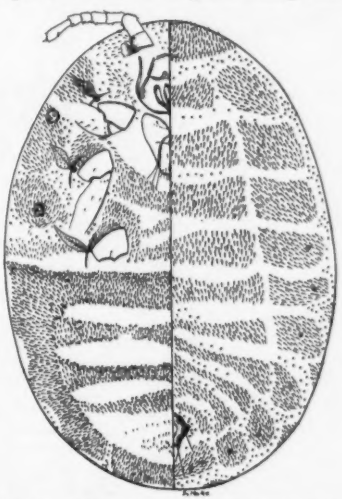


FIG. 19.—*Orthezia lasiorum:* Adult female, body, dorsal and ventral; × about 31

within the outer margin; ovisac band inclosing 3 broad, heavy, and 2 narrower, lighter bands of spines and pores, the first 3 of these extending broadly to the ovisac band on each side; anal ring elongate oval, heavily chitinized, with a relatively narrow pore band on each half, this made up of comparatively few pores and indefinitely angulate anteriorly and posteriorly, the 2 pore bands distinctly separated anteriorly and barely touching posteriorly, the middle of the outer face of each half of the anal ring with a protruding triangular chitinous wing, and just beyond this, on each side, 3 to 6 smaller, stout conical spines, this species differing, in the possession of the last, from all of the other species of the genus examined; anal ring with the usual 6 setae.

This species has been redescribed from the following material: A single mutilated specimen, mounted on a slide, from Las Vegas, N. Mex., in nests of *Lasius americanus*, collected by Mrs. T. D. A. Cockerell, April, 1901 (type).

ORTHEZIA LONGIPES HEMPEL

Figs. 3, L; 5, L; 7, H; and 20; Pl. 1, I

REFERENCE.—Hempel, 1920 (rec'd 1921), Rev. Mus. Paulista 12: 343, 345, 367–368.

ADULT FEMALE.—Very closely related to *O. praelonga* Dougl., differing clearly from that species, as usually recognized, only in the possession of a more elongate, asymmetrical conical eyestalk and of scattered spines just within the ovisac band anteriorly and posteriorly in addition to the normal 4 transverse rows or bands of spines.

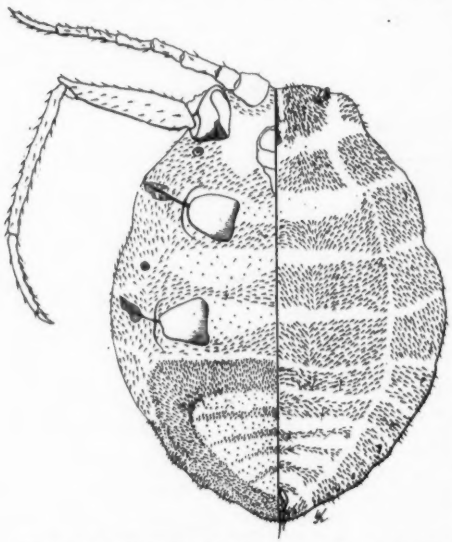


FIG. 20.—*Orthezia longipes:* Adult female, body, dorsal and ventral; × about 31

The great kindness of the describer of the species, Mr. Hempel, in inducing the authorities of the Museo Paulista to send cotype specimens for examination has made it possible to compare this species with other members of the genus and to associate it in the relationship indicated.

The species is known only from the original collection at Rio de Janeiro, Brazil, on an undetermined native plant.

ORTHEZIA MEXICANA, NEW SPECIES

Figs. 3, M; 6, A; and 21; Pl. 1, J

ADULT FEMALE.—Stout oval, length of body with secretion about 1.8 millimeters, width about 1.1 millimeters, length of ovisac about 2.2 millimeters, completely covered dorsally with well-developed tufts of white secretionary matter, these arranged in the usual marginal and dorsal plates, the posterior marginal tufts increasing in length and projecting backwards over the ovisac; ovisac distinctly ribbed dorsally; length of body as mounted about 2.1 millimeters, width 1.7 millimeters, stout oval, tapering slightly anteriorly, posterior apex broadly rounded; derm membranous; antennae normally 8-segmented, the measurements of the segments of one in microns as follows: I, 132; II, 114; III, 94; IV, 93; V, 82; VI, 75; VII, 61; VIII, 158; spine, 36; eyestalk short, rounded conical, small; legs characteristic for the genus, rather short and stout, tarsal claw, at most, with a very indistinct denticle; setae on legs small, slender, spinelike, tarsal digitules relatively slender; beak elongate conical, 1-segmented, but with a quite distinct suggestion of a joint about one-third of length from base; thoracic spiracles characteristic for the genus, each opening into a spine cluster, and with spines grouped about this opening to form a very indefinite collar; with 7 pairs of large, short tubular abdominal spiracles; derm pores of the usual quadrilocular disk type, occurring rather commonly both dorsally and ventrally and very numerous in the ventral abdominal area inclosed by the ovisac band; derm with occasional setae both dorsally and ventrally, these most abundant in a well developed cluster anterior to the genital opening; body spines arranged in the usual 11 marginal and 10 dorsal clusters, about as shown in figure, the dorsal abdominal bands narrowed through much of their length, but broadened exteriorly, and all extending close to the marginal bands on each side; body spines, in general, rather elongate, slender, stout at base, tapering strongly near base, then gradually, to an almost pointed tip, but with the spines in the last pair of dorsal abdominal bands distinctly

shorter and smaller than those in the remainder; ventral ovisac band broad, made up of closely crowded spines, with bands of disk pores 3 or 4 deep extending through the exterior fourth or fifth of the band, but without any distinct pores along the inner margin, in this respect differing from most of the species in the genus, the concentration of disk pores usually occurring in or along the inner rather than the outer margin; ovisac band enclosing, besides the pores already mentioned, 5 more or less distinct transverse rows of small truncate conical tubercles, these occupying the position of and apparently corresponding to the rows of ventral abdominal spines found in nearly all the other species in the genus; anal ring stout oval, the pore band on each half broad, slightly joined at the ends, and distinctly and prominently angulate within anteriorly and posteriorly; with the usual 6 anal ring setae.

This species has been described from three mounted and a few unmounted adult females from Mexico (no definite locality) on roots of *Parthenium argentatum* (Compositae), collected by F. E. Lloyd, received February 5, 1909.

The types are in the United States National Collection of Coccidae.

FIG. 21.—*Orthezia mexicana:* Adult female, body, dorsal and ventral; × about 31

ORTHEZIA MINOR, NEW SPECIES

Figs. 3, N; 6, B; 7, I; and 22; Pl. 1, K

ADULT FEMALE.—Small, length of body with secretion about 2 millimeters, width about 1 millimeter, completely covered dorsally and ventrally with strongly developed plates of waxy secretion, buff-colored in the specimens examined, these arranged in the usual lateral and dorsal plates, the anterior

FIG. 22.—*Orthezia minor:* Adult female, body, dorsal and ventral; × about 31

median plate directed forward, long and deeply notched apically, the anterior lateral marginal plates very irregular, the posterior lateral plates increasing in length to the apical one or two, these quite long, anterior dorsal plates fused into a single transverse plate directed forward; the second pair separated, but also directed forward; remaining plates very strongly and conspicuously developed, directed diagonally backward and outward, overlapping for much of their length; ovisac short (possibly incompletely developed), only about 1 millimeter long; length of body, asmounted, 1.25 millimeters; width, 0.9 millimeter, ovoid, posterior apex broadly rounded, tapering anteriorly; derm membranous; antennae normally 8-segmented, rather elongate, measurements of one in microns as follows: I, 107; II, 100; III, 114; IV, 71; V, 78; VI, 75; VII, 76; VIII, 210; eyestalk rather elongate tubular; beak conical, 1-segmented, with a fairly distinct suggestion of a division near base; legs characteristic for the genus, relatively long as compared to the size of the body, rather slender, tarsal claw usually with 2 fairly distinct denticles on the inner face; thoracic spiracles not unusual, each opening into the usual spine cluster, with a few spines directly

encircling the opening but without a conspicuous spine collar around this, with, so far as can be determined, 4 pairs of long tubular abdominal spiracles; derm with the usual quadrilocular disk type of pores occurring both dorsally and ventrally, these all apparently rather lightly chitinized; with setae occasionally both dorsally and ventrally, these slightly but not conspicuously clustered anterior to the genital opening; with the usual 11 marginal and 10 dorsal clusters of spines, the latter broad, complete bands, each extending close to its corresponding marginal cluster on each side; ovisac band broad, interrupted posteriorly, made up of spines only,

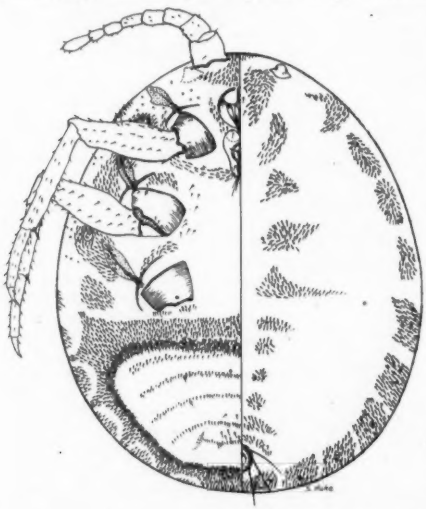


FIG. 23.—*Orthezia monticola:* Adult female, body, dorsal and ventral; × about 31

with a single row of scattered quadrilocular disk pores along the posterior margin, these somewhat larger and more heavily chitinized than the average for the remainder of the body; band inclosing 5 narrow, well-separated, loose transverse rows of spines, the anterior 3 extending close to the ovisac band on each side, the posterior 2 distinctly shorter; anal ring short oval, almost circular, pore band on each half divided into two parts posterior to the middle seta only, broad, plainly but not conspicuously angulate anteriorly and posteriorly, the ends of the two halves slightly but distinctly separated from each other; with the usual 6 anal ring setae.

This species has been described from two mounted and a very few unmounted specimens from Loona de Joaquin, Oriente Province, Cuba, on *Graffenriedia chrysandra* (Melanostomaceae), collected by C. H. Ballou and S. C. Bruner, July 20, 1922 (coll. No. 366).

The types are in the United States National Collection of Coccidae.

ORTHEZIA MONTICOLA COCKERELL

FIGS. 3, O; 6, C; and 23; Pl. 1, L

REFERENCE.—Cockerell, 1898, Ann. and Mag. Nat. Hist. (7) 2: 402.

ADULT FEMALE.—Dried body very broad oval, nearly circular, naked dorsally except for marginal and paired median tufts of secretion, in this respect superficially resembling *Orthezia insignis* to a marked degree, marginal tufts of secretion flattened, platelike, somewhat curved, the posterior ones much longer, sometimes approximating half the length of the body and distinctly separated for their entire length up to the anal tufts; ovisac variable in length, maximum apparently nearly 3 millimeters broad, distinctly ribbed dorsally; body color of dried specimens dark chestnut brown; length of body as mounted 2.1 millimeters, width 1.75 millimeters; derm membranous; antennae normally 8-segmented, length of segments of one in microns as follows: I, 114; II, 107; III, 125; IV, 103; V, 96; VI, 86; VII, 79; VIII, 143; spine, 15; eyestalk flat conical, apex rounded, legs characteristic for the genus, rather stout, tarsal claw fairly stout, with 2 or 3 indistinct denticles on the inner face; beak short and stout conical; thoracic spiracles characteristic for the genus, opening in a cluster of spines, but without distinctly developed spine collar; with 7 pairs of tubular abdominal spiracles; derm pores of the usual quadrilocular disk type, occurring both dorsally and ventrally, varying distinctly in extent of chitinization and size; derm with a few scattered setae both dorsally and ventrally, these more abundant in a loose cluster anterior to the genital opening; derm spines arranged in the usual dorsal and marginal clusters, widely separated, but with a slight tendency on the part of the dorsal clusters to form a transverse band; ovisac band fairly stout anteriorly, narrowed posteriorly, made up

of numerous spines with a relatively large number of disk pores scattered through the inner one-third to one-half of the band; area inclosed by the band with 5 narrow bands of scattered spines extending nearly to the ovisac band on each side; anal ring elongate oval, the pore band on each half rather narrow and not angulate within; anal ring with the usual 6 setae.

This species has been redescribed from the following material: Dripping Springs, Organ Mts., N. Mex., on roots of grass (Gramineae), coll. T. D. A. Cockerell (type material). The species does not appear to have been observed since its original discovery.

ORTHEZIA NIGROCINCTA COCKERELL

Figs. 3, P; 6, D; 7, J; and 24; Pl. 1, M

REFERENCE.—Cockerell, 1895, Amer. Nat. 29: 730.

Adult female.—Dried body nearly circular, about 2.25 millimeters long by 2 millimeters wide; with the usual marginal tufts of secretion, these all fairly long, mostly curved backward and flattened over the ovisac, and with the usual series of dorsal tufts, but these distinctly separated from the body margin by a bared blackish band on each half, this band, however, narrower than in either *insignis* or *monticola*, the combination of dorsal tufts occupying fully two-thirds of the disk of the dorsum, tufts narrow and erect anteriorly, broader and considerably wider through the thoracic segments and again narrower, except for the last pair, in the abdominal region, closely approximated along the median line, with only a linear bare streak more or less definitely exposed; ovisac attaining a length greater than that of the body, distinctly ribbed dorsally, slightly curved upward and slightly tapering posteriorly; body of female as mounted about 2 millimeters long by 1.5 millimeters wide, oval, tapering somewhat anteriorly; derm membranous, except for an elongated, more or less definitely defined, chitinized plate running back dorsally from the anterior margin of the head; antennae normally 8-segmented, measurements of one in microns as follows: I, 125; II, 100; III, 140; IV, 125; V, 115; VI, 100; VII, 103; VIII, broken; eyestalk stout conical, apex rounded, heavily chitinized; legs not unusual for the genus, fairly stout, tarsal claw with 2 or 3 indistinct denticles on the inner face; beak fairly long conical, 1-segmented, with a suggestion of a joint sometimes visible near base; thoracic spiracles entirely characteristic for the genus, the opening surrounded by an indefinite collar of smaller, stouter spines; with 8 pairs of short tubular abdominal spiracles; derm with the usual quadrilocular disk pores, both dorsally and ventrally, these varying conspicuously in size, most abundant in the ventral area inclosed by the ovisac band; derm with occasional setae dorsally and ventrally, these most abundant in a definite cluster just anterior to the genital opening; body spines arranged in the usual 11 marginal and 10 dorsal clusters on each half, about as shown in figure, the dorsal clusters, while distinctly and mostly widely separated from the corresponding marginal clusters, at the same time plainly transverse; ventral ovisac band rather stout, composed of numerous spines with an irregular row of disk pores 2 or 3 deep along the inner margin; ovisac band enclosing 3 short, transverse, narrow rows of spines, none of these extending to or even close to the ovisac band at the sides; anal ring elongate oval, the pores on each half united or nearly so anteriorly and posteriorly, and the inner margin of each pore band fairly distinctly angulate anteriorly and posteriorly; ring with the usual 6 setae.

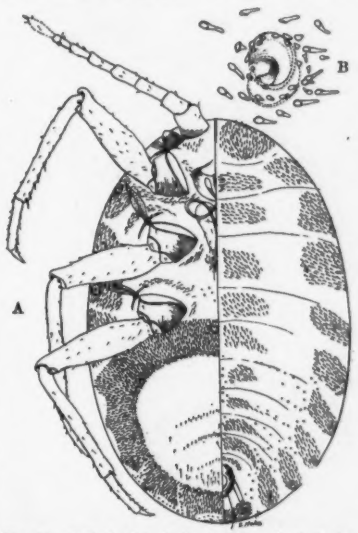


FIG. 24.—*Orthezia nigrocincta*, adult female: A, body, dorsal and ventral, × about 31; B, opening of thoracic spiracle, showing greatly reduced spines at edge of opening, × 230

The following material has been examined in connection with the redescription of this species: Mescalero Agency, N. Mex., on Gutierrezia (Com-

positae), coll. C. H. T. Townsend, Oct., 1896 (Div. Ent. No. 7288 (type); Beulah, N. Mex., on Artemisia (Compositae), coll. T. D. A. Cockerell, Aug., 1899; Las Valles, N. Mex., coll. T. D. A. Cockerell, Aug., 1899; Las Valles, N. Mex., coll. T. D. A. Cockerell, received July, 1907.

The published records add Embudo, N. Mex., to the distribution given in the preceding paragraph, but no other hosts.

ORTHEZIA NUDA FERRIS

Figs. 3, Q; 6, E; 7, K; and 25; Pl. 2, A

REFERENCE.—Ferris, Contr. Knowl. Cocc. S. W. U. S. Stanf. Univ. Pub. Univ. Ser., 1919, p. 13.

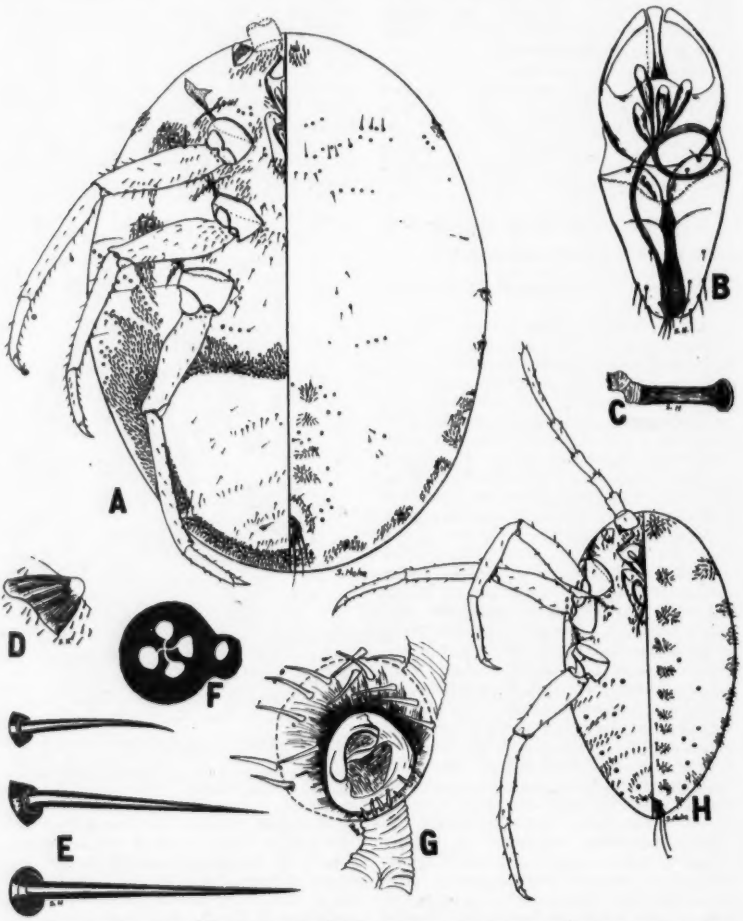
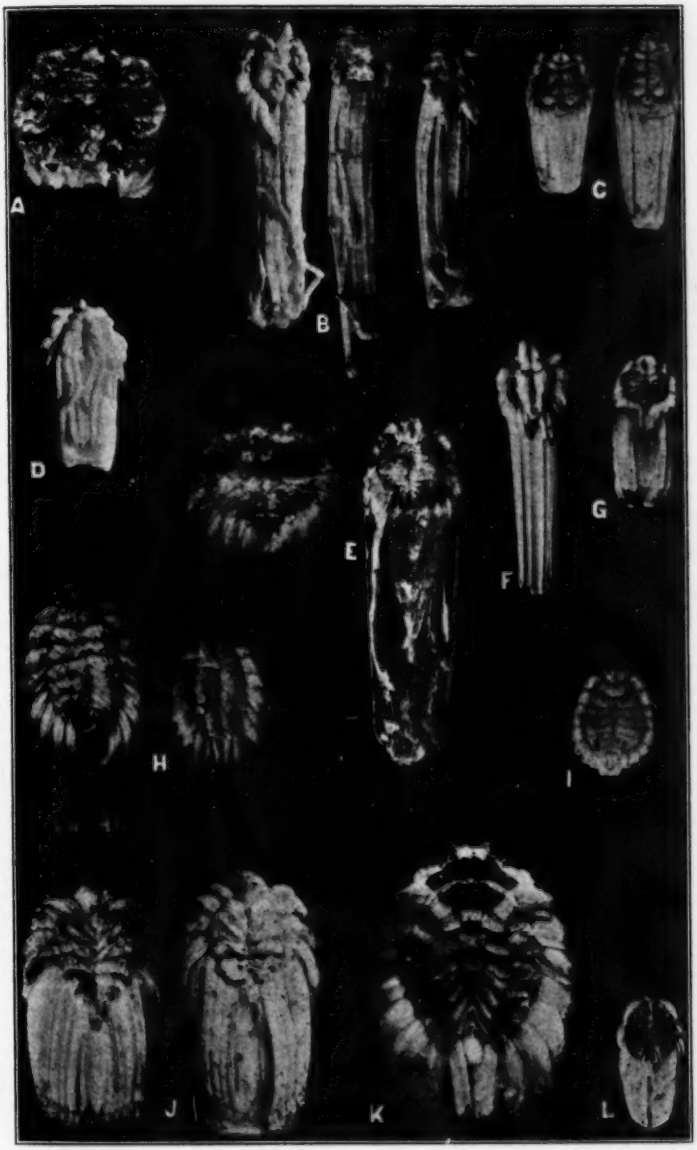


FIG. 25.—*Orthezia nuda:* A, adult female, body, dorsal and ventral, × 23; B, same, beak, × 60; C, same, eyestalk, × 60; D, same, abdominal spiracle, × 230; E, same, body setae, × 650; F, same, quadrilocular disk pore, with simple pore adjacent, × 1,500; G, same, thoracic spiracle, × 230; H, larva, body, dorsal and ventral, × 60.

ADULT FEMALE.—Dried and somewhat shriveled female dark reddish brown, margin lighter, translucent, length of body with ovisac 4 milimeters, width of body 2.5 milimeters, body dorsally destitute of secretion except



Scale Insects of the Subfamily Orthezilnae Plate 2

A, *Orthezia nuda*, adult female, ovisac wanting; B, *O. praelonga*, adult females, secretion mutilated; C, *O. pseudograminis*, adult females (photo by J. G. Sanders); D, *O. solidaginis*, adult female (photo by J. G. Sanders); E, *O. sonorensis*, adult females, secretion mutilated; F, *O. tillandsiae*, adult female; G, *O. ultima*, adult female; H, *O. urticae*, adult female and immature female; I, *O. cataphracta*, adult female, ovisac wanting; J, *Newsteadia americana*, adult females; K, *Orthezia occidentalis*, adult female, ovisac obscured; L, *Nipponorthezia ardisiae*, adult female, secretion incomplete

for 2 small tufts on the head between antennae and, normally, 5 indistinctly separated, small, median, paired tufts on the abdomen just anterior to the anal ring; anterior lateral margins of body likewise destitute of secretion, caudal margin with 3 tufts on each side of the middle line, and a fourth, smaller, just outside the third, but placed somewhat ventrally instead of at the margin; ovisac, in the specimens examined, short, very little longer than broad, with 8 more or less distinct dorsal ribs and fine longitudinal striations ventrally; body, as mounted on slide, stout oval, nearly as wide as long, length 3 millimeters, width slightly less; derm membranous except for a pair of elongate triangular transverse thickenings opposite genital opening ventrally; antennae normally 8-segmented, apparently not unusual; legs characteristic for the genus, tarsal claw rather stout, claw digitules stout, spinelike, inner face of claw with 3 denticles; eyestalk conical, apex rounded, with a more or less developed basal chitinous lip; beak of medium size, short conical, apex rounded, 1-segmented, but with a fairly distinct suggestion of a joint about one-third of its length from the base, apex bearing several stout setae; thoracic spiracles characteristic for the genus, the openings of each surrounded by a cluster of spines, with a few of these shorter and otherwise modified from the typical forms; with 8 pairs of elongate tubular abdominal spiracles; derm pores of the quadrilocular disk type only, but of two sorts, one, the larger, heavily chitinized, with relatively large loculi and relatively small marginal rim, these occurring mostly scattered over the dorsal surface but occurring also, somewhat reduced in size and distinctly reduced in chitinization, in connection with the ovisac band and elsewhere in the ventral region, the other, much more faintly chitinized and with relatively much smaller loculi and larger marginal rim, occurring chiefly in the midventral abdominal region within the area surrounded by the ovisac band, many of these, particularly among the larger dorsal pores, with one or more short lateral chitinous extensions, each running to and surrounding a small, simple, clear circle or with such small circles close to but separated from the disk pore; these disk pores scattered, except along the inner margin of the ovisac band, here mostly closely crowded and extending perhaps one-fourth of its width through the band; body with rather stout setae, apparently indiscriminately scattered over it, or rarely, as in the midventral region, in indistinct transverse rows, and with 1 transverse cluster anterior to the genital opening; spines present dorsally in a paired transverse cluster just anterior to the anal ring and in 4 pairs of small irregular median clusters on the abdominal segments just anterior to this, these spines stout, normally tapering only very slightly after the initial constriction at the bases, and with their apices bluntly rounded; with a small, probably paired, marginal tuft at the anterior apex of the body; a small marginal tuft opposite each anterior spiracle and undoubtedly with small marginal clusters responsible for production of the marginal abdominal tufts of secretion along the apex and sides of this, but these so mutilated in the few specimens available for study that little can be said regarding their character; ovisac band rather narrow, composed of spines similar to, but more slender and less heavily chitinized than, those found dorsally, accompanied by a band of pores several deep along the inner margin and extending into the spine band for some distance, inclosing at least 3 transverse rows of spines; anal ring characteristic for the genus except that the inner margins of the pore band are not angularly produced near the anterior and posterior ends; with the usual 6 anal ring setae.

LARVA.—Oval, somewhat tapering behind, short, length about 715 microns; width about 430 microns; antennae 6-segmented, the terminal fully twice the length of any of the others; eyestalk conical; legs not unusual, claw slender, with 2 distinct denticles and well developed, spinelike digitules; beak 1-segmented; thoracic spiracles not unusual; abdominal spiracles elongate, slender, with 8 pairs as in adult; derm spines tapering; with occasional quadrilocular disk pores, these in more or less distinct longitudinal rows; ventrally bearing transverse submarginal segmental rows of elongate, rather slender spines in the abdominal region, these clusters more irregular in shape than in the thoracic region, and dorsally with small, submedian clusters of similar spines the whole length of the body and somewhat similar marginal tufts corresponding segmentally with the median; anal ring not unusual.

Owing to the discovery of 8 pairs of abdominal spiracles and of small clusters of spines on the dorsum of the abdomen, the specimens available for study were originally described as a new species, but through the great kindness of Professor Ferris in loaning the single mounted specimen of his

species, it has been possible to ascertain that these specimens are actually identical with his species, although his description should be corrected with respect to these two points in its structure. In having the dorsal spine clusters that are present of very small size and in two longitudinal rows on the abdomen, the species resembles *monticola* and *insignis*, from which it can be definitely separated, not only by the incompleteness of the dorsal spine rows and secretion, but by the presence of 8 pairs of abdominal spiracles.

This species has been redescribed from two mounted adult females, one unmounted female, and several mounted larvae collected by H. S. Barber and Dr. E. A. Schwarz in the Santa Rita Mountains, Ariz., June 14, 1905, on an unknown host. The type specimens of the species were collected near Benson, Ariz., on *Quercus emoryi* (Fagaceae) by Prof. Ferris, June, 1918.

ORTHEZIA OLIVACEA COCKERELL

Figs. 3, R; 6, F; 7, L; and 26

REFERENCE.—Cockerell, 1905, Canad. Ent. 37: 136.

ADULT FEMALE.—No specimens available for description of external appearance, the following, therefore, copied from the original description: "Length about 2.5 mm., with cauda rather over 3 mm., legs and antennæ reddish-brown. Body entirely covered with dense white secretion; dorsal line marked by a deep groove, with no median tufts; the two dorsal rows of lamellæ thick and obtuse, the first pair overlapping head, but not projecting far forward; area between dorsal and lateral lamellæ covered by secretion; lateral lamellæ broad, the anterior three truncate, the others more pointed, the points curved inward; caudal lamellæ surpassing last lateral ones, but not very long. Body denuded of lamellæ dark olivaceous." Length of body as mounted about 2.25 millimeters, width 1.75 millimeters, uniformly oval; derm membranous; antennæ normally 7-segmented, lengths of one in microns as follows: I, 96; II, 89; III, 93; IV, 50; V, 50; VI, 46; VII, 139; spine, 21; eyestalk very small, flattened, the eyespot occupying most of the tuberculate center; legs rather small, fairly stout; setae slender, tarsal claw with 2 or 3 fairly distinct denticles on the inner face; beak stout conical, 1-segmented, but with a rather distinct suggestion of a joint near the base; thoracic spiracles characteristic for the genus, each opening within a spine cluster and this opening surrounded by a rather definite collar of somewhat smaller and shorter spines; with 8 pairs of long tubular abdominal spiracles; with the usual quadrilocular disk type of pores only, these occurring both dorsally and ventrally, mostly not heavily chitinized, very abundant in the posterior portion of the area inclosed by the ovisac band; derm with a few scattered setae both dorsally and ventrally; derm spines arranged in the usual 11 marginal and 10 dorsal clusters, about as shown in figure, the dorsal bands fully developed and extending almost to the corresponding marginal bands on each side; ovisac

FIG. 26.—*Orthezia olivacea:* Adult female, body, dorsal and ventral; × about 31.

band stout, made up of spines with disk pores along the anterior margin, with a scattered row of distinctly smaller disk pores just within the inner margin of the band; inclosing 5 transverse bands of spines, the 3 anterior of these broad and extending fully to the ovisac band on each side; anal ring stout oval, the pores on each half produced within anteriorly and posteriorly but not angularly, meeting anteriorly but slightly separated behind; ring with the usual 6 rather long setae; with tiny hemispherical tubercles scattered through the areas between the spine clusters on each side of the anal ring, both dorsally and ventrally.

This species has been redescribed from the following material: From

Boulder, Colo., in nests of *Lasius* sp. under rocks, coll. W. P. and T. D. A. Cockerell, November, 1904 (type), and Colo. with ants, coll. C. F. Baker, about 1897 (from Tinsley collection).

The species was also recorded in the original description as occurring at Trout Spring, N. Mex.

ORTHEZIA PRAELONGA DOUGLAS

Figs. 3, S, T; 6, G; 7, M; 27 and 28; Pl. 2, B

REFERENCE.—Douglas, 1891, Ent. Mo. Mag. 27: 246–247.

ADULT FEMALE.—Length of adult female with secretion nearly 2 millimeters, width 1.25 millimeters, ovisac variable in length, sometimes as much as 6 millimeters long, more or less dis-

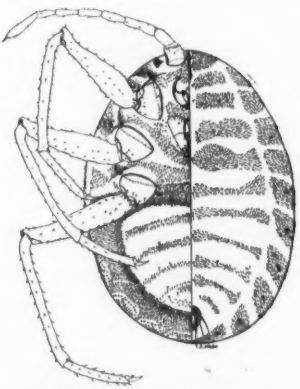


FIG. 27.—*Orthezia praelonga:* Adult female, body, dorsal and ventral; × about 31

tinctly ribbed dorsally, body completely covered with very fragile white secretion dorsally, showing a more or less distinct, but at most narrow, bare streak near each margin, separating the dorsal and marginal plates, secretion evidently arranged in the usual lateral and dorsal tufts, but invariably so confused medially, in museum specimens, as to make its accurate description practically impossible; the 2 anterior marginal plates elongate conical, protruding directly forward, the next lateral marginal plates also elongate, protruding directly laterad, the remaining marginal plates more and more strongly curved backward, with the plates of the apical pairs quite long, projecting over the ovisac; the 2 anterior pairs of dorsal plates directed forward, the next nearly erect, and the remainder directed somewhat backward and overlapping; ventral surface completely covered with secretion except at the insertions of the appendages; body of female, as mounted, about 1.5 millimeters long by 1 to 1.25 millimeters wide, rarely somewhat larger than this; uniformly oval, or somewhat narrowed anteriorly; derm membranous, except for a narrow, dorsal, chitinized, median stripe running backward from a point at or close to the anterior margin, varying somewhat in length and width, and frequently, but not always, expanded at or near the posterior apex; antennae normally 8-segmented, but often abnormal, as few as 5 segments having been observed, lengths of segments of one in microns as follows: I, 118; II, 93; III, 157; IV, 124; V, 118; VI, 107; VII, 114; VIII, 221; spine, 22; eyestalk rounded tuberculate, somewhat conical, small; legs quite long in proportion to the size of the body, in this respect resembling *insignis*, moderately slender, bearing slender setae, tarsal claw with 2 distinct, but not prominent, denticles on the inner face, more rarely with a slight swelling suggesting the presence of a third basad to the other 2; beak conical, apex rounded, 1-segmented, with a very faint suggestion of a division line near base occasionally showing; thoracic spiracles entirely characterictic for the genus, opening in a spine cluster and with some spines grouped about the opening in the form of an indistinct spine collar; with 7 pairs of long tubular abdominal spiracles; derm pores of the usual quadrilocular disk type, occurring both dorsally and ventrally, varying somewhat in size and chitinization, most abundant along the margin of the ovisac band, but also fairly numerous in the posterior ventral abdominal area; derm with scattered slender setae both dorsally and ventrally, in addition with some small spinelike setae just anterior to the genital opening, and with a considerable number of small circular clear disks with chitinized rims in a loose cluster posterior to the same, and to a less extent anteriorly among the clusters of small setae; derm spines arranged in the usual 11 marginal and 10 dorsal clusters about as shown in figure, the dorsal abdominal bands rather narrow, with wide interspaces, and, while continuous to the marginal bands on each side, somewhat more widely separated from the last than in many other species, the spines composing them more loosely and less definitely grouped than in many of the other species; ovisac band broad, made up of spines, with the addition of a large number of disk pores, in a row 4 to 6 deep clear around the inner margin of the band and partly confused with the

spines along this margin and, along the anterior margin of the band, in a similar pore row, averaging about 3 to 5 deep, and definitely intermingled with the spines making up the band along this margin; ovisac band interrupted laterally and posteriorly, inclosing 4 distinctly separated transverse bands of scattered spines, these extending to the ovisac band on each side, the anterior 2 about 3 or 4 spines wide, the posterior 2 narrower, the last composed mostly of only a single row of spines; anal ring oval, characteristic for the genus, the pore bands on each half slightly separated at their ends and the inner margin of the same distinctly and acutely angulate anteriorly and posteriorly; with the usual 6 anal ring setae, these rather long and slender.

FIG. 28.—*Orthezia praelonga:* Map showing actual known distribution. Large dots show records based on specimens actually examined; small dots show records based on published reports of occurrence.

Material from the following localities has been more or less carefully examined during the preparation of the preceding description: Barbados, Bolivia, Brazil, British Guiana, Canal Zone, Ecuador, Grenada, Panama, St. Croix (Virgin Islands), and Trinidad. Published distribution records add Antigua, Dominica, Jamaica, and St. Kitts to the above list.

The host records, both for material examined and from published information, include: Capsicum (Solanaceae), Carica (Passiflorae), Citrus (Rutaceae), Cocoloba (Polygonaceae), Codiaeum (Euphorbiaceae), Coffea (Rubiaceae), Euphorbia (Euphorbiaceae), Gossypium (Malaceae), Haematoxylon (Leguminosae), Hyptis (Labiatae), Lonicera (Caprifoliaceae), Loranthus (Loranthaceae), Malphigia (Malphigiaceae), Parderia (Rubiaceae), Rosa (Rosaceae), Saccharum (Gramineae), Sanchezia (Acanthaceae), and Sapium (Euphorbiaceae).

ORTHEZIA PSEUDOGRAMINIS, NEW SPECIES

Figs. 3, U, and 29; Pl. 2, C

ADULT FEMALE.—External appearance in general resembling that of *graminis* very closely, differing principally in the following details: Dorsal bare strip on each half of the body normally extending only over about the anterior half of the body length, the remainder of this area covered with secretion, although not with prominent erect plates; marginal fingerlike tufts of secretion along the posterior portion of the body somewhat longer than in *graminis;* ovisac averaging not more than two-thirds of the maximum length of that of *graminis* in specimens examined; shape of body, as mounted, much as in *graminis,* size averaging slightly smaller; relative lengths of antennal segments approximately the same; legs somewhat stouter than in *graminis;* tarsal claw with denticles; dorsal and marginal spine clusters in general corresponding to those of *graminis,* but with the dorsal abdominal clusters forming complete bands extending to the corresponding marginal clusters and separated from the same only by a narrow clear area, and with the two posterior dorsal thoracic clusters united with the corresponding marginal clusters by a very narrow band of scattered spines.

FIG. 29.—*Orthezia pseudograminis:* Adult female, dorsal and ventral; × about 31

This species has been described from the following lots of material: Sterling, Colo., on *Sporobolus cryptandrus* (Gramineae), coll. E. O. G. Kelly, July, 1908 (type and paratypes); Lamar, Colo., on *Deschampsia cespitosa* (Gramineae), coll. E. D. Ball, Sept., 1898 (paratypes); Pecos, Tex., on salt grass (*Distichlis spicata*) (Gramineae), coll. C. N. Ainslie, July, 1908 (paratypes); Mesilla Park, N. Mex., on grass (Gramineae), Oct. 19, 1897, coll. Cockerell (paratypes).

The types are in the United States National Collection of Coccidae.

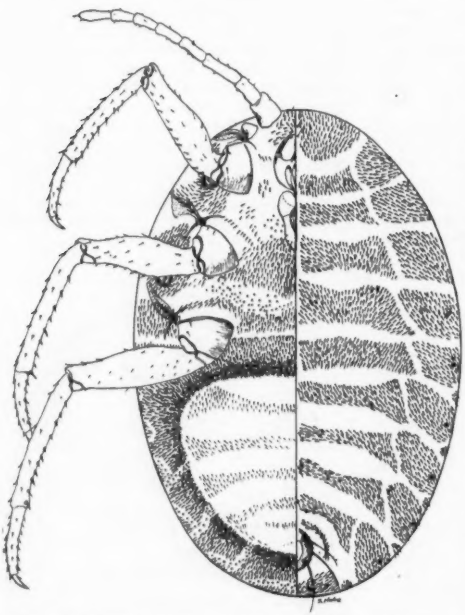


FIG. 30.—*Orthezia solidaginis:* Adult female, dorsal and ventral; × about 31

The species described above is extremely close to typical *graminis*, differing definitely only with respect to the extent of the lateral development of the dorsal spine bands as described and illustrated, and it has, in consequence, been very reluctantly characterized as new, since it seems not entirely unreasonable that these dorsal bands might vary to this extent. The material at hand, however, where in a condition for accurate study, fails to disclose any marked variation in series of specimens from any one lot, or anything approximating a definite range of intergradation between the conditions of the spine development which appear to delimit the two species. The apparent occurrence of both species at Mesilla Park is evidence in favor of the assumption that the difference in the extent of the lateral development of dorsal spine bands is merely due to variation, but such an assumption needs verification by some positive evidence of variation or intergradation before it can be fully accepted and thespecies described herewith as new be reduced to synonymy. This description will at least serve to emphasize the need for an examination of a long series of specimens of these grass-inhabiting forms.

ORTHEZIA SOLIDAGINIS SANDERS

Figs. 3, V; 6, H; and 30; Pl. 2, D

REFERENCE.—Sanders, 1904, Ohio Nat. 4: 94–95, pl. 8, figs. 57–63.

SYNONYM.—*Orthezia ambrosiae* Lawson, 1917, Univ. Kan. Bul. Biol. Ser. 18: 165–167, fig. 1.

ADULT FEMALE.—External appearance described in detail by Sanders in his original description, and by Lawson under the name *ambrosiae*, and illustrated in photograph accompanying this paper. Length of body, with ovisac, 6 to 7.5 millimeters; width about 2.5 millimeters; length of body, as mounted, about 2.75 millimeters; width about 2 millimeters, oval, tapering more or less distinctly anteriorly; derm membranous; antennae normally 8-segmented, measurements of one in microns as follows: I, 160; II, 143; III, 246; IV, 164; V, 171; VI, 150; VII, 133; VIII, 200; spine, 21; eyestalk rather strongly protruding, conical tuberculate; legs characteristic for the genus, rather long and slender, tarsal claw usually with 3 distinct denticles on the inner face; beak conical, 1-segmented, with a fairly distinct indication of a division line about one-third of the length from base; thoracic spiracles characteristic for the genus, the opening of each surrounded by a distinct and rather conspicuous, closely set collar of spines, a portion of this collar resting on a somewhat chitinized curved plate following the outline of the opening; with 8 pairs of long tubular abdominal spiracles; with the usual quadrilocular disk pores, these present both dorsally and ventrally, more numerous in and along the inner margin of the ovisac band and also rather abundant through-

out the area inclosed by this band; derm with an occasional seta both dorsally and ventrally; body spines arranged in the usual 11 marginal and 10 dorsal clusters, about as shown in figure, the dorsal clusters extending close to the marginal, with the outer end of dorsal cluster and the inner end of the marginal cluster sinuous so that the two overlap each other more or less obviously; ovisac band broad, interrupted posteriorly by 3 transverse clear bands on each side, made up of numerous crowded spines, and, through the inner third particularly, numerous and rather crowded disk pores, anterior margin with a more or less definite single row of these pores; ovisac band inclosing 5 transverse rows of spines, these distinctly and rather widely separated from one another, but, excepting the last, extending to the ovisac band at each end and more or less distinctly broadened at the ends; anal ring elongate oval, the pores on each nearly contiguous at the ends, although not united, the inner margins acutely angulate anteriorly and posteriorly; with the usual 6 fairly long setae, and with a few tiny clear disks on each side of the anal ring and more of these ventrally behind the anal ring, these apparently similar to those already described for *praelonga* and *olivacea*.

The preceding redescription of this species has been based on the type specimens from Columbus and Sandusky, Ohio, on *Solidago canadensis* (Compositae), coll. J. G. Sanders, Oct., 1902, and July, 1903, and on specimens from St. Louis, Mo., on Solidago, coll. Otto Lugger, July, 1872 (No. 234 L). Material from Plummers Island, Md., on Solidago, coll. J. G. Sanders, Oct., 1908, and from Round Hill, Va., on Potentilla (Rosaceae), coll. J. G. Sanders, Sept., 1909, has also been available. The published records add Kansas to the distribution and *Ambrosia trifida* (Compositae) to the known hosts.[5] The synonymy indicated for *ambrosiae* Lawson has been based on an examination of specimens received from Prof. Lawson by the Bureau of Entomology.

ORTHEZIA SONORENSIS COCKERELL

Figs. 3, W; 6, I; and 31; Pl. 2, E

REFERENCE.—Cockerell, 1896, U. S. Dept. Agr. Div. Ent. Tech. Ser. 4: 38–39.

ADULT FEMALE.—Very closely resembling *Orthezia annae;* antennae normally 8-segmented, measurements of one in microns as follows: I, 107; II, 126; III, 150; IV, 100; V, 103; VI, 89; VII, 85; VIII, 160; disk pores along inner margin of ovisac band somewhat less numerous than in *annae*, fewer of the inner spines of the posterior dorsal clusters reduced in size than in *annae*.

LARVA.—In general resembling that of *annae* quite closely, but differing conspicuously in that the antennae of all the specimens examined are only 5-segmented, with the third segment very long, as compared with the normal 6 segments present in the larva of *annae*, this difference apparently furnishing the only positive means of differentiating these two species.

FIG. 31—*Orthezia sonorensis:* Adult female, body, dorsal and ventral; × about 31

This species has been included in this paper on the basis of material from San Ignacio, Sonora, Mexico, on *Hymenoclea monogyra* (Compositae), coll. C. H. T. Townsend, Sept. 26, 1894 (type). It does not appear to have been observed since the publication of the original description.

[5] See also *Orthezia americana*, as most of the records for that species probably actually apply to *O. solidaginis*

ORTHEZIA TILLANDSIAE, NEW SPECIES

Figs. 4, A; 6, J; 7, N; and 32; Pl. 2, F

ADULT FEMALE.—Size small, average length of body with secretion 1.5 millimeters, average width of body with secretion nearly as much; ovisac when fully developed very elongate, total maximum length of ovisac and body observed 9 millimeters, average length approximately 6 millimeters, ovisac widest at base, tapering slightly posteriorly, more or less curved in a horizontal plane when fully developed, about as wide as the body of the insect and distinctly narrower than the body on each side, by a similar line isolating the median tufts of secretion from the marginal tufts; each margin of body with fingerlike tufts of secretion, the anterior curving forward, placed opposite the base of the anterior median tuft, the remainder curving backward with gradually increasing emphasis, until the posterior 2 are reached, these longer and more slender than the others; ovisac definitely, but not prominently, ribbed or fluted dorsally and laterally, only finely striated ventrally; body ventrally nearly as completely covered with secretion as the dorsal surface but the secretion

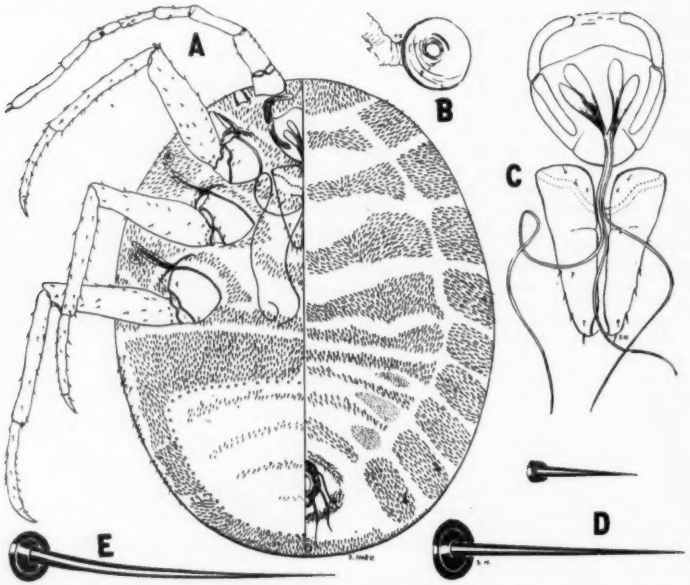


FIG 32.—*Orthezia tillandsiae*, adult female; A, body, dorsal and ventral, × about 60; B, thoracic spiracle, × 335; C, mouth parts, × 120; D and E, body setae; × 1,500

with its secretion; body of female covered with firm waxy secretion divided into plates, with 2 very long anterior plates projecting well out beyond the head, 2 much smaller, transverse, just behind these, 3 pairs of semierect, posteriorly directed plates covering the disk of the thoracic region, and, in direct continuation of these, 6 similar plates gradually reduced in size posteriorly and usually so fused together that the actual number present is not determinable, these 2 rows of plates distinctly separated from each other by an impressed median line penetrating to the derm, and laterally, here much thinner and less prominent; average length of body as mounted on slide 1.3 millimeters, average width 0.9 millimeter; derm membranous except for 3 pairs of, usually, quite distinct, transverse, irregular to oval, somewhat chitinized areas placed dorsally on each side of the outer ends of, and between, the second to fifth transverse rows of spines anterior to the anal ring; antennae normally 8-segmented, the lengths of these for one antenna in microns as follows: I, 107; II, 89; III, 114; IV, 64; V, 93; VI, 75; VII, 79; VIII, 160; spine, 18; eyestalk nearly as long as wide, only slightly conical,

apex rounded, average length about 43 microns, width at base 50 microns; legs characteristic for the genus, tarsal claw nearly straight, fairly stout, with 2 distinct and sometimes 1 indistinct denticle within, claw digitules relatively slender; beak not unusual, length of that of an average specimen 196 microns, width at base 175 microns; 1-segmented, with only a faint fold about one-third of length from base suggesting a joint; thoracic spiracles not unusual, with a cluster of spines of normal shape and size around the opening of each; abdominal spiracles short and relatively stout, very obscure, owing to the close crowding of the body spines; exact number not absolutely determinable, but apparently with 4 pairs, these the 4 posterior ones; derm pores, so far as observed, of the one characteristic quadrilocular disk type only, occurring sparingly, except in the midventral abdominal region, here in rather closely set, irregular, transverse rows, particularly around the genital opening, and these last pores somewhat larger and less heavily chitinized and with a wider marginal rim than those occurring dorsally and laterally; body with scattered setae dorsally and laterally, in more or less distinct relation to the spine clusters, and with a distinct transverse cluster of setae of varying sizes just anterior to the genital opening, as well as with indistinct transverse rows of such setae anterior to this cluster; body spines distinctly set off in groups corresponding to the secretion as already described, the disk of the dorsum with 10 paired transverse clusters on the head, thorax, and abdomen, of which the first 4 are distinctly larger and broader than those on the abdomen; marginal spines, including the anterior head clusters and the posterior abdominal one, in 11 clusters on each side of the body, these placed more or less directly opposite the ends of the corresponding transverse dorsal clusters; anterior section of ovisac band relatively broad, accompanied only by a single row of scattered quadrilocular disk pores, lateral and apical sections of this band somewhat narrower, likewise accompanied only by the single row of pores, this band interrupted laterally by narrow, diagonal clear areas, and inclosing, in the midventral abdominal region, 3 narrow, curved, widely separated, transverse rows of short spines; with clusters of spines around the openings of the thoracic spiracles, but none of these unusual in shape; also with clusters and patches of spines around the coxae; anal ring of normal form for the genus, the inner margin of the pore band on each half strongly angulate within anteriorly and posteriorly, the angulate tongues nearly inclosing a membranous area at each end of the ring; with the usual 6 anal ring setae.

LARVA.—Ovate, tapering somewhat behind, average length 464 microns, average width 303 microns, eyestalk short tuberculate, antennae not unusual, lengths of segments of one in microns as follows: I, 32; II, 39; III, 43; IV, 50; V, 50; VI, 121; spine, 21; legs normal, fairly stout, tarsal claw with 2 prominent denticles on the apical half, and frequently with a somewhat less conspicuous one about the middle, claw digitules set alike, and not over one-fourth the length of the claw; beak elongate conical, average length about 93 microns, average width at base about 71 microns; thoracic spiracles not unusual; abdominal spiracles apparently in 4 pairs as in adult; with a few scattered derm pores, these forming short, indefinite, median transverse segmental rows dorsally in the thoracic region; body with a few, apparently scattered, setae and numerous spines, the last arranged in definite clusters dorsally and on the abdomen ventrally, the median and marginal dorsal groups closely approaching each other, so that there appears to be an almost continuous transverse band of spines on each segment; ventral rows of spines on abdomen narrower, with the spines less numerous and more scattered; ring not unusual for the genus.

This species has been described from two mounted adult females from Elfers, Fla., on Spanish moss (*Tillandsia usneoides*) (Bromeliaceae), collected July 12, 1917, and forwarded by C. E. Wilson (holotype and paratype), and from six mounted adult females, five mounted larvæ, and a number of unmounted specimens from Motes Station, Fla., on *Tillandsia usneoides*, collected by H. W. Fogg, October, 1921, and July, 1922, and kindly forwarded for study by G. E. Merrill of the Florida State Plant Board (paratypes). Material from Gainesville, Fla., collected July, 1924, by Hart and Merrill, has also been reported.

The types are in the United States National Collection of Coccidae. Paratypes are in the collection of the Florida State Plant Board.

ORTHEZIA ULTIMA COCKERELL

Figs. 4, B; 6, L; and 33; Pl. 2, G

REFERENCE. — Cockerell, 1902, Canad. Ent. 34: 88–89.

ADULT FEMALE.—Body of female, with secretion, about 1.5 millimeters

long by about 1.3 millimeters wide; ovisac usually ranging from 1.5 to about 3 millimeters long; body covered dorsally with white secretion, except for a narrow band on each side, this curved toward the median line at the posterior end, running most of the length of the body, but terminated anteriorly by the first lateral marginal plate and posteriorly by the terminal dorsal plates, the wax arranged in the usual marginal and dorsal plates but those of the dorsum not sharply differentiated, the anterior lateral plates short and stout, gradually increasing in length posteriorly and the posterior pair more or less distinctly longer than the remainder; body of female, as mounted, about 1.5 millimeters long by 1.3 millimeters wide, uniformly oval, or more or less distinctly tapering anteriorly; derm membranous, except for a definitely developed, very elongate oval, usually distinctly chitinized, thickened plate running back along the dorsal median line from the anterior apex of the head, and an elongate thickening ventrally on each side of the genital opening; antennae normally 8-segmented, the segments short and stout as compared with practically all of the other species in the genus, measurements of those of one antenna in microns as follows: I, 79; II, 71; III, 94; IV, 66; V, 61; VI, 55; VII, 57; VIII, 125; spine, 21; eyestalk rather flat conical, apex rounded; legs short, in agreement with the antennal length, fairly stout, entirely characteristic for the genus, tarsal claw with 2 or, more rarely, 3 fairly distinct denticles on the inner face; beak rather stout conical, with an indistinct suggestion of a division near base; thoracic spiracles characteristic for the genus, opening in a spine cluster and with some spines close to the opening, but without an evidently developed spine collar; with 7 pairs of long tubular abdominal spiracles; derm pores of the usual quadrilocular disk type, occurring both dorsally and ventrally, most abundant in the inner portion of the ovisac band; derm with slender setae occurring occasionally both dorsally and ventrally; derm spines arranged in the usual 11 marginal and 10 dorsal clusters on each half of the body, the dorsal clusters distinctly forming transverse bands, but plainly and even rather widely separated from the corresponding marginal clusters, particularly on the abdomen, this clear area accounting for the narrow bare stripe visible between the dorsal and marginal plates of secretion in the perfect specimens; ovisac band broad, interrupted posteriorly, composed of numerous spines and crowded with disk pores along the inner margin and through the inner fourth; band inclosing 4 loose and narrow transverse rows of spines, all of these, except the last, extending well toward the ovisac band on each side; anal ring characteristic for the genus; bands of pores on each side joined, or nearly so, at the ends, the inner margin of each distinctly but not prominently angled anteriorly and posteriorly; ring with the usual 6 setae.

FIG. 33.—*Orthezia ultima*, adult female: A, body, dorsal and ventral, × about 31; B, section of anterior median portion of ovisac band; × about 60

This species has been redescribed from the following material: From Ceres, Santa Fe Province, Argentina, probably on a composite, collected by L. Bruner in 1902 (type). It does not appear to have been observed since originally collected.

ORTHEZIA URTICAE (LINNAEUS)

Figs. 4, C; 6, M; 7, O; and 34; Pl. 2, H

REFERENCE.—Linnaeus, 1758, Systema Naturæ, ed. 10, p. 453 (as Aphis).

SYNONYMS.—*Orthezia characias* Bosc, *Dorthezia dispar* Kalt., *Coccus dubius* Fabr., *Aphis urticata* Stewart (see Fernald, 1903, Cat. Cocc. World, p. 36); *Dorthezia delavauxii* Thieb., "*Coccus glecomae* Fabr." Dougl. (see Lindinger, 1912, Die Schildläuse, p. 367, and Fernald, 1903, Cat. Cocc. World, p. 34); *Orthezia maenariensis* Dougl. (see Laing, 1922, Ent. Mo. Mag. 58: 254); *Orthezia japonica* Kuw., *Orthezia martelli* Leon.

ADULT FEMALE.—Total length of body with ovisac, in material examined, about 5 millimeters, but as much as 10 millimeters according to published descriptions; total length of body with caudal plates about 3.5 millimeters; ovisac variable; width of body with secretion 2.5 millimeters; body completely covered dorsally with well-developed plates of secretion, these

fairly distinctly segregated into the usual marginal and dorsal plates, the anterior marginal tufts relatively short and stout, increasing in length and becoming more slender and fingerlike posteriorly, anterior dorsal paired tufts, at most, only indistinctly divided along the median line, the remaining dorsal pairs distinctly separated by a triangular groove, dorsal tufts transverse, each somewhat pointed nearer the middle than the margin, and the outer third of each tuft very often separated from the remainder by a light diagonal impressed line, this producing the appearance of an additional separate tuft of secretion between the corresponding median and marginal tufts, this appearance, however, not correlated with any corresponding segregation of the spines in the dorsal spine bands of the body; ovisac strongly ribbed dorsally; body closely resembling *O. solidaginis* in morphological characters, differing noticeably only in the following details: Length of body as mounted 3.25 millimeters, width 2. 5 millimeters; measurements of segments of one antenna variable, in microns as follows: I, 172; II, 150; III, 185; IV, 160; V, 136; VI, 111; VII, 114; VIII, 196; eyestalk rather elongate conical, nearly always bearing a very distinct lateral tubercle on the anterior margin, rarely with 2 such tubercles; tarsal claw usually with 2, more rarely with 3, not very distinct denticles on the inner face; collar of spines surrounding opening of each thoracic spiracle even more developed and more conspicuous than in *solidaginis*, the chitinous rim supporting the spines completely encircling the opening of the spiracle; ovisac band resembling that of *solidaginis* closely, except that in the section between and immediately behind the posterior legs the disk pores that are distributed through the posterior third of the band in *solidaginis* occur along the posterior margin in *urticae*, although distributed through the lateral section of the ovisac band much as in *solidaginis*.

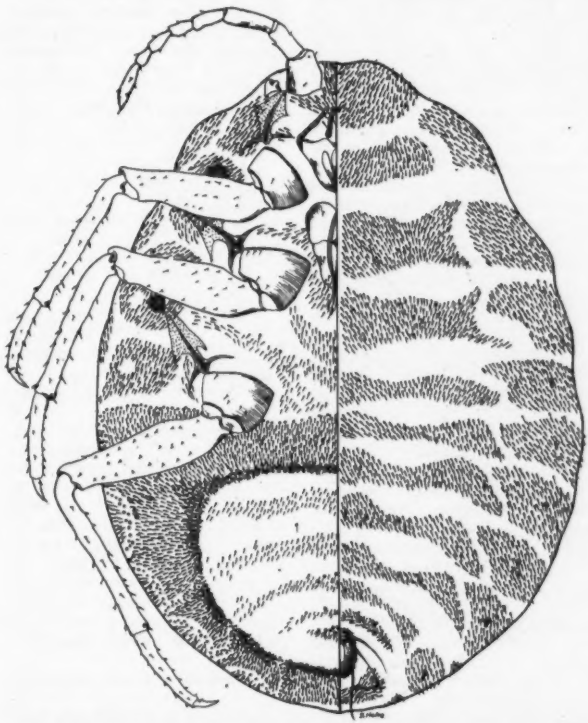


FIG. 34.—*Orthezia urticae:* Adult female, body, dorsal and ventral; × about 31

This species has been redescribed from material from France, Prussia, and Askhabad, Transcaspia, Central Asia. The published distribution records include Algeria, Austria, Bohemia, Corfu, England, France, Germany, Greece, Italy, Moravia, and Tyrol.

The synonyms listed for this species, excepting two only, have been accepted on the basis of published references, mostly in European literature. The writer has had an opportunity to examine specimens of an Orthezia collected by Prof. T. D. A. Cockerell at Tsuruga, Japan, on *Medicago denticulata* (Leguminosae) which appear to agree entirely with Kuwana's description of *Orthezia japonica*, and which it has not been possible to separate from *O. urticae*, all of the presumably important characters agreeing very closely with those of European specimens of that species available for comparison. Through the great kindness of Dr. F. Silvestri the writer has also been able to examine a single adult female from the type material of *Orthezia martelli* Leon., with the result that this species is, in his opinion, identical with *O. urticae*. It should be noted, however, that this conclusion has been based on the examination of a single decidedly imperfect specimen.

The known host records include Achillea (Compositae), Aegopodium (Umbelliferae), Artemisia (Compositae), Aster (Compositae), Ballota (Labiatae), Caltha (Ranunculaceae), Centaurea (Compositae), Compositae, Coronilla (Leguminosae), Cuscuta (Convolvulaceae), Erica (Ericaceae), Euphorbia (Euphorbiaceae), Galium (Rubiaceae), Geranium (Geraniaceae), Glaux (Primulaceae), Glecoma (Labiatae), Gramineae, Hedera (Araliaceae), Heracleum (Umbelliferae), Hieraceum (Compositae), Humulus (Moraceae), Labiatae, Lathyrus (Leguminosae), Leontodon (Compositae), Matricaria (Compositae), Melampyrum (Scrophulariaceae), Melittis (Labiatae), Onobrychis (Leguminosae), Parietaria, (Urticaceae) Phlomis (Labiatae), Rubus (Rosaceae), Stellaria (Caryophyllaceae), Symphytum (Boraginaceae), Taraxacum (Compositae); Teucrium (Labiatae), Trifolium (Leguminosae), Tunica (Caryophyllaceae), Urtica (Urticaceae), Vinca (Apocynaceae).

ORTHEZIA VARIPES (LEONARDI)

Figs. 4, D; 6, K; and 35

REFERENCE.—Leonardi, 1911, Bol. Lab. Zool. Gen. e Agr. R. Scu. Sup. Portici 5: 240–243, fig. 2, 3.

Through the courtesy of Dr. F. Silvestri the writer has been permitted to examine a single specimen from the type material of this species. The condition of the microscopic mount prepared from this specimen is such that no satisfactory outline drawing showing the position and relation of the body structures can be prepared. However, it can be determined that the species is extremely closely related to *O. ultima* Cockerell, differing positively, so far as the writer has observed, only in that the anterior median section of the ovisac band has disk pores distributed through the inner two-thirds of its width, in that there is not an evident single row of disk pores along the anterior margin of the band, and in that, in this section at least, the row of disk pores along the inner or posterior margin is not more than two deep while it is as much as three or four deep in *ultima*. It seems possible that the examination of additional and better material of both species may demonstrate that they are identical. As nearly as can be determined, the arrangement of the spine clusters and bands is practically identical with that found in *ultima*, and it is necessary to remark particularly on the fact that these, as shown in Leonardi's drawing of the denuded adult female, are very incomplete and inaccurate. The species was described from Cacheuta, Argentine Republic, collected on *Atriplex lampa* (Chenopodiaceae).

FIG. 35.—*Orthezia varipes:* Adult female, section of anterior median portion of ovisac band; × about 115

ORTHEZIA YASHUSHII KUWANA

REFERENCE.—Kuwana, 1923, Dept. Agr. and Com. [Japan] Imp. Plant Quar. Sta. Bul. 3: 58–63, fig. 5, pl. 14.

An extended description of this species, accompanied by a number of figures, appeared in the above publication, the edition of which was almost totally destroyed by the Japanese earthquake of September, 1923. From the description it appears to the present writer that this species, on comparative study, may prove to have been based on nothing more than small-sized or somewhat stunted adults of *O. urticae*. It has not been possible to include it in the key. The species

was described from two of the larger islands of Japan and was recorded as occurring on wild chrysantheum (Compositae) and *Artemisia vulgaris* (Compositae).

SUBGENUS ARCTORTHEZIA COCKERELL

REFERENCE.—Cockerell, 1902, Entomologist 35: 114, 259. (As a section.)

The structural and other characters of this subgenus agree with those given in the generic diagnosis, except for the differences already emphasized in the key to the subgenera. The subgenus includes two well known species, one of which, as indicated by the map accompanying the discussion of it, has a holarctic distribution, while the other is thus far known only from the Western States and mostly, but not entirely, from rather high altitudes.

The host relationships of the two included species, so far as they are known, do not appear to possess particular significance.

The two species placed here may be separated by the following key:

KEY TO SPECIES OF THE SUBGENUS ARCTORTHEZIA

a. Median triangular spine groups relatively large, extending the full depth of the segment bearing each and completely isolating the two halves of the dorsal spine band on each; corresponding dorsal secretionary plates of perfect insect large, distinctly overlapping each other or the following segment----------*occidentalis* Douglas.

aa. Median triangular spine groups much smaller, extending over only about the anterior half of the depth of the segment bearing each and not isolating the halves of the dorsal band; corresponding secretionary plates of the perfect insect small, not reaching the following segment in any case--*cataphracta* (Shaw).

ORTHEZIA CATAPHRACTA (SHAW)

Figs. 3, E; 6, N; 7, P; 36 and 37; Pl. 2, I

REFERENCE.—Shaw, 1794, Naturalist's Miscellany 5: 182.

SYNONYMS.—*Dorthezia chiton* Zetterstedt, *Orthezia signoreti* F. B. White, and *Orthezia uva* Blanchard (see Fernald, 1903, Cat. Coc. World, p. 33).

ADULT FEMALE.—Broad oval, tapering somewhat anteriorly, size variable, length with secretion about 3.5 millimeters, width 2.5 to 3 millimeters; completely covered dorsally and ventrally with heavy plates of white secretion, except at the insertions of the appendages; ovisac short and broad, parallel-sided, extending about 1.5 to 2 millimeters beyond apex of body; dorsal wax plates complete, each half with 10 visible marginal plates, including the fused anterior median one, and 9 visible median transverse plates, all

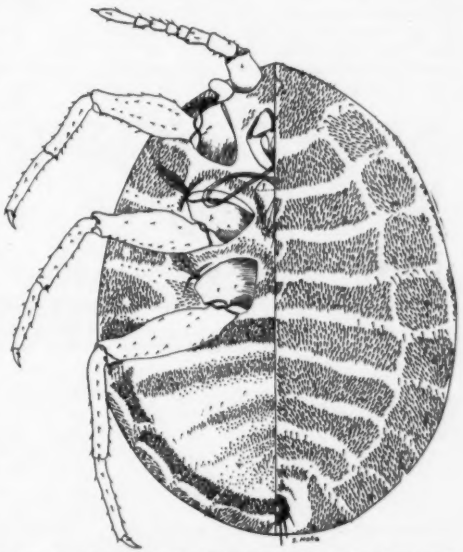


FIG. 36.—*Orthezia cataphracta:* Adult female, body, dorsal and ventral; × about 31

paired except the posterior one, these occupying most of the dorsal area; differing noticeably from the other members of the genus, except *occidentalis*, in the possession of 3 unevenly diamond-shaped or triangular wedges of secretion along the middle line, one on each half of the last 2 thoracic and the first abdominal segments; body without secretion averaging 2 to 2.5 millimeters in length and 1.5 to 2 millimeters in width; stout oval, posterior end broadly rounded, anterior end somewhat tapering; derm membranous, except for appendages and a slightly chitinized thickening ventrally on each side of the genital opening; antennae normally 8-seg-

mented, all of the segments relatively short and stout; average lengths of the different segments in microns as follows: I, 196; II, 139; III, 89; IV, 51; V, 68; VI, 71; VII, 71, VIII, 214; eyestalk strongly produced, curved, thumblike, not distinctly conical; legs characteristic for the genus; tarsal digitules short, stout, spinelike, tarsal claw without denticle; beak stout conical, 1-segmented, the joint figured by List[6] in his elaborate monograph of the species not found in the specimens available for examination; thoracic spiracles not unusual, the openings placed rather close to the bases of the anterior and intermediate legs, not distinctly surrounded by a collar of spines; with 7 pairs of short tubular, abdominal spiracles; derm pores, so far as observed, of the quadrilocular disk type only, these scattered, rather rare on the dorsal surface, most noticeable in the interspaces between the bands of spines, more abundant ventrally in rather definite transverse bands, alternating with the spine bands, in the region inclosed by the ovisac band; none of these pores very heavily chitinized; body bearing inconspicuous, slender setae, scattered, or in indefinite rows, and very numerous, rather stout spines in bands corresponding to the superficial secretion and about as figured, this including 10 marginal clusters, counting the anterior one, and 10 dorsal clusters on each half of the body, the last, just anterior to the anal ring, quite small, and its secretion concealed from view by the posterior unpaired plate formed by the spine cluster just preceding it; the 3 small triangular plates of secretion on the middle line represented by 3 indistinctly isolated, small, triangular clusters of spines not wholly interrupting the transverse spine bands in which they occur; ovisac band composed of spines only, relatively narrow as compared with many of the species in the genus, the lateral portions cut by clear transverse lines; band inclosing 3 definite, continuous, transverse bands of spines, of which the anterior is much the heaviest and continued for its full width nearly to the ovisac band at each end, while the 2 posterior taper laterally and terminate before attaining the ovisac band; anal ring stout oval, more or less distinctly pointed posteriorly, with numerous pores, conspicuously angulate internally on each half, and with the usual 6 anal ring setae, these of moderate length.

This species has been redescribed from the following material: From Cooper Island of the Commander Islands, off Siberia, taken from the gullet of *Leucosticte griseonucha* a "rosy finch," by Dr. L. Stejneger, June 28, 1883, and from St. Anthony, Newfoundland, on *Iris setosa* (Iridaceae), collected at quarantine, Washington, D. C., by H. L. Sanford, September 15, 1916. The published European and other distribution records include "among the Alps," Austria, Bohemia, England, Greenland, Ireland, Lapland, Norway, Scotland, Siberia, Styria, Sweden, and Switzerland. The published host records include Calluna (Ericaceae), Carex (Cyperaceae), Geranium (Geraniaceae), grass (not specified) (Gramineae), Hymogyne (Compositae), mosses (not specified) (Musci), Rhacomitrium (Musci), Saxifraga (Saxafragaceae), Soldanella (Primulaceae), Sphagnum (Musci).

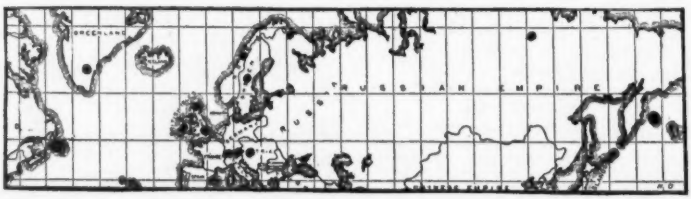


FIG. 37.—*Orthezia cataphracta:* Map showing actual known distribution. Large dots show records based on specimens actually examined; small dots show records based on published reports of occurrence

ORTHEZIA OCCIDENTALIS DOUGLAS

Figs. 4, F; 6, O; and 38; Pl. 2, K

REFERENCE.—Douglas, 1891, Ent. Mo. Mag. 27: 245.

SYNONYM.—*Orthezia californica* Ehrhorn (see Ferris, 1920, Stanf. Univ. Pub. Univ. Ser. Biol. Sci. 1: 13.

ADULT FEMALE.—Body, with secretion, fairly large, total length to end of

[6] List, J. H. Ztschr. Wiss. Zool. 45: 201-286, pl. 1-6, 1887.

caudal appendages 4.5 millimeters, total width 3.25 millimeters; body completely covered with dense, sharply defined wax plates, these occurring in the usual marginal and dorsal tufts, white or variously discolored, sometimes appearing yellow-brown or gray, but with only 10 marginal tufts, instead of the 11 found in typical Orthezia, these all more or less definitely flattened, the lateral and posterior ones curved and directed backward and from one another, the first 3 by large flattened, triangular, overlapping plates set on the median line, the remainder by a triangular depression, the last visible pair of dorsal tufts fused into a single plate; body, as mounted, stout oval, length about 3.5 millimeters, width about 3 millimeters, derm membranous; antennae normally 8-segmented, lengths of one in microns as follows: I, about 250; II, 215; III, 121; IV, 100; V, 89; VI, 93; VII, 111; VIII, 235; spine, 21;

FIG. 38.—*Orthezia occidentalis:* Adult female, body, dorsal and ventral; × about 31

downward, gradually increasing in length posteriorly so that the apical 3 or 4 overlap the ovisac to a marked degree; ovisac short and stout, not much, if any, longer than the body, distinctly ribbed dorsally; anterior pair of dorsal plates fused into a single transverse lobe, the members of each of the following 7 pairs distinctly separated eyestalk strongly tuberculate, finger-like, curved, length through longitudinal axis about 162 microns; width about 72 microns; each placed immediately adjacent to a basal antennal segment; legs stout, the setae on the different parts heavy and spinelike, tarsal claw without any distinct denticles on the inner face, although fre-

quently very slightly thickened at a point corresponding with the usual location of the outer denticle; beak rather long conical, 1-segmented, with a faint suggestion of a joint sometimes visible near the base; thoracic spiracles not unusual, each opening in a spine cluster, without a definite spine collar around the opening, but with a fairly distinct band of disk pores surrounding each opening; with 7 pairs of very short tubular abdominal spiracles; derm pores of the usual quadrilocular disk type only, these occurring both dorsally and ventrally, particularly in the interspaces between the spine bands; derm with scattered, slender setae both dorsally and ventrally; derm spines arranged in 10 marginal and 10 dorsal, compact, closely crowded clusters, with the second, third, and fourth dorsal bands completely interrupted medially by broad, triangular, similarly crowded spine clusters set off from the remainder of the band on each side by narrow diagonal clear strips, these last clusters evidently forming the 3 triangular wax plates of the perfect insect; ventral ovisac band stout anteriorly, somewhat narrowed laterally and interrupted by several clear spaces; anal ring oval, with the pore bands on each half united at anterior and posterior apices, and each very strongly angulate along the inner margin at three points, one opposite each anal ring seta; the usual 6 anal ring setae rather long and slender.

This species has been redescribed from the following material: West Cliff, Custer County, Colo., in nests of *Formica integra*, coll. T. D. A. Cockerell, 1889 (cotype); Beulah, N. Mex., coll. T. D. A. Cockerell, March, 1900; the same, no date, coll. Miss W. Porter; Kaslo, British Columbia, on roots of trees and grass amongst rotten wood, coll. J. W. Cockle, April and May, 1908; Corte Madera Creek, Stanford University, Calif., on *Eriophyllum confertifolium* (Compositae), coll. M. N. Reeper, October, 1916; Boulder, Colo., on *Castilleja* sp. (Scrophulariaceae), coll. at quarantine, Washington, D. C., by H. F. Dietz, June 8 and 12, 1917; near Eldorado, Colo. (9,000 feet), coll. T. D. A. Cockerell, October 1, 1922. The following are the additional published distribution records for the species: Colorado, near Fort Collins; New Mexico, at Trout Springs; California, in Marin County. There are no other published host records, although the species has been reported as occurring in ants' nests.

GENUS NEWSTEADIA GREEN

REFERENCE.—Green, 1902, Ent. Mo. Mag. 38: 284–285.

The following diagnosis may be given for this genus:

ADULT FEMALE.—Completely covered externally with depressed or flattened tufts or plates of secretion, much as in Orthezia; ovisac, when fully developed, about as long as the body; derm without definite chitinization except for a transverse median plate in the posterior ventral abdominal region in one species; antennae normally 6 to 7 segmented, the 2 basal segments very much enlarged and elongated as compared with Orthezia; eyestalk elongate, curved, fingerlike; legs similar to those of Orthezia, except for the complete fusion of the tibia and tarsus in each, the joint indicated only as a more or less distinct transverse line near base; beak 1-segmented, rather elongate conical, rounded at apex; with the usual 2 pairs of thoracic spiracles and with 5 anterior pairs of abdominal spiracles, the posterior pairs wanting; derm pores of the quadrilocular disk type; derm setae occurring occasionally over body and in a distinct cluster ventrally, anterior to the genital opening; body spines arranged in marginal and dorsal clusters as in Orthezia, but most of the marginal abdominal clusters fused into a conspicuous band; anal ring with the usual pore bands and 6 setae, the latter rather short, stout, and blunt-tipped as compared with Orthezia.

LARVA.—Very similar to that of Orthezia, differing primarily in the possession of only 4-segmented antennae.

ADULT MALE.—Not exhibiting any characters that will plainly segregate males of this genus from those of Orthezia.

This genus has previously been represented by only a single species, this occurring naturally in various parts of Europe, and, presumably through accidental introduction and under rather peculiar circumstances, in one place in Australia. A second, American, species is described below. This genus, excluding the Australian record, therefore has a holarctic distribution, and a majority of the records appear to be from northern localities or rather high altitudes, an apparently conspicuous exception to this being the principal record on which the new American species is based, this being from an altitude only a little above sea level, and latitude 39 degrees north. The original collector of the species has

suggested, however, that it was possibly introduced at this point from a higher altitude through deposition of driftwood or other trash from upstream, and its recent discovery in such a higher altitude, toward the headwaters of the stream along which it was first found, tends to strengthen this hypothesis.

The host relations of the species of the genus are not altogether certain, but it seems probable that its members may feed either on fungus hyphae of the types that form long rootlike cords extending over and through rotted wood, or on the more or less exposed roots of higher plants.

The two species now included in this genus may be separated by the following key:

KEY TO SPECIES OF THE GENUS NEWSTEADIA

a. Antennae normally 6-segmented; no elongate, transverse, chitinous thickening ventrally and posteriorly just inside ovisac band; intermediate dorsal abdominal spine bands narrow, constricted, but not definitely interrupted where crossing the median line; length about 1.6 mm.....*floccosa* (De Geer).

aa. Antennae normally 7-segmented; with a distinct, elongate, transverse, chitinous thickening ventrally and posteriorly just inside ovisac band; intermediate dorsal abdominal spine bands broader, strongly constricted and nearly, if not quite, interrupted over the median line; length about 2.7 mm.....*americana*, new species.

NEWSTEADIA AMERICANA, NEW SPECIES

Figs. 39 and 40; Pl. 2, J

Occurring in moist situations beneath rotten bark, on rotten logs, and in trash; possibly feeding on the roots of trees, shrubs, or plants that had forced their way into the situation mentioned; no definite host or hosts assignable.

ADULT FEMALE.—Completely covered dorsally by heavy, definitely arranged plates of secretion, and at maturity secreting an ovisac equaling or sometimes exceeding the body in length; maximum length of body and ovisac secretion 6 millimeters, width 3 millimeters; dorsal secretion arranged as follows: 1 large, median, triangular plate projecting from the anterior apex of the body; 1 similar but much smaller just behind this; 7 large, transverse, paired median plates, separated by a fairly distinct median impressed division line, of which the second, third, and fourth from the anterior end are the largest and of which the first 3 protrude diagonally forward and upward, the fourth directly upward, and the remaining 3 diagonally outward and slightly backward, all these not standing up prominently, but rather flattened; posterior to the last paired plate with a relatively long and narrow single median wax plate protruding backward above the anal opening, and beneath this plate with a much smaller paired plate, with its parts often fused more or less distinctly to the single plate above and wholly concealed as the insect is viewed from above; lateral secretion, as distinct from that forming the ovisac, composed of 4 stout, curved, somewhat fingerlike plates, of which the posterior is much the longest and flattened and curved around the anterior ends of the ovisac; ovisac usually distinctly ribbed, the dorsal half made up of 8 overlapping ribs, ventral half made up of almost smooth or at most very finely striated secretion strongly curved to inclose numerous oval eggs, these pale yellow, at least after death; body ventrally likewise completely covered with secretion arranged in definite plates; body of female, as mounted on slide, short oval, sometimes nearly circular; average length 2.5 millimeters, average width 2.2 millimeters; derm membranous except for appendages and a single, elongate, transverse, more or less distinctly chitinized ventral plate posterior to the genital opening; antennae normally 7-segmented, rarely 5- or 6-segmented, the basal segment very long and stout, the second segment about as long as the first, but much more slender, and more or less distinctly constricted just before the apex, the remaining segments much shorter and progressively shorter up to the next to the last, apical segment about as long as second and with a long slender spine and 1 stout seta at its tip, the average length of the different segments in microns as follows: I, 268; II, 221; III, 61; IV, 54; V, 46; VI, 46; VII, 196; apical spine, 114; various antennal segments with a number of slender spines, those of the intermediate segments on the apical margins of each and those on the remaining segments more or less scattered through the length except on the basal, here more

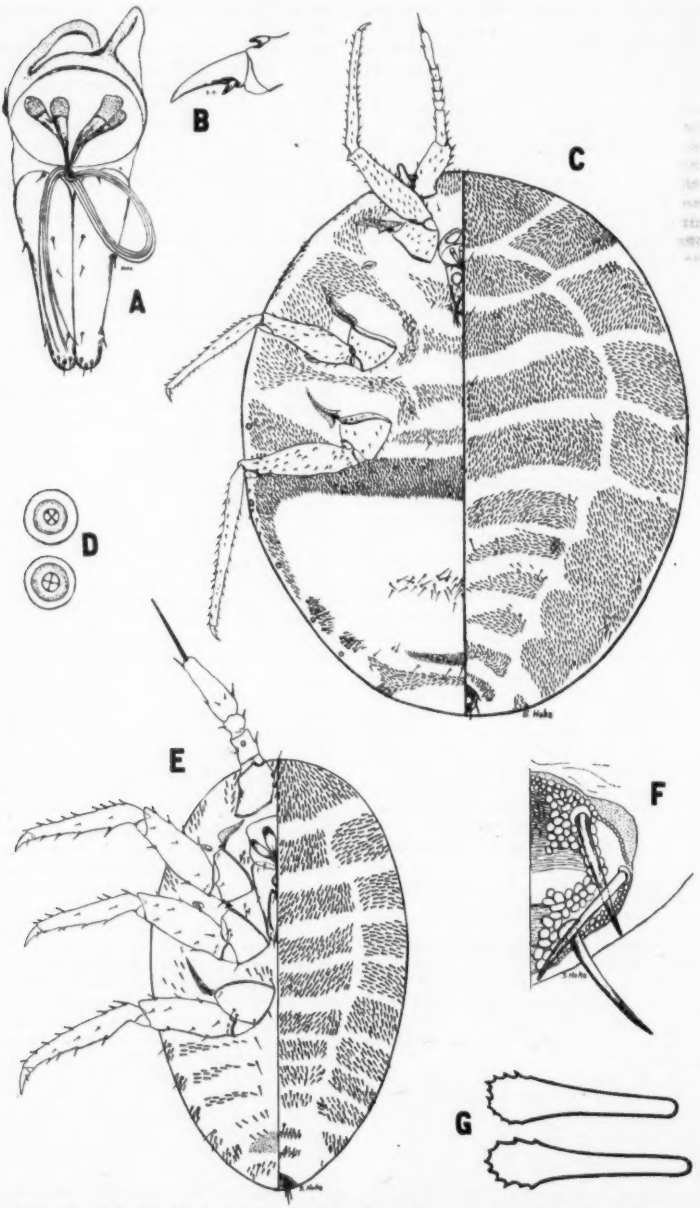


FIG. 39.—*Newsteadia americana:* A, adult female, beak, × 120; B, same, tarsal claw, × 230; C, same, body, dorsal and ventral, × about 31; D, same, quadrilocular disk pores, × 1,500; E, larva, body, dorsal and ventral, × 230; F, adult female, anal ring, showing pores and setæ, × 335; G, same, dorsal spines; × 1,500

slender and occurring on the apical half only; eyestalk elongated, almost fingerlike, slightly curved; average length 114 microns, width at base 68 microns; legs fairly large and stout, the joints between trochanter and femur and between tibia and tarsus completely obliterated except only for a diagonal line near the base of the latter combination, parts bearing numerous, but not grouped or crowded, slender spines, these appearing to have a more or less definite arrangement on the combined tibia and tarsus; tarsal claw slender, only slightly curved and enlarged at base, without denticles; tarsal digitules short spines, not more than one-eighth the length of the claw; trochanter with 3 to 4 oval pores on each face; beak 1-segmented, elongate, only slightly tapering; somewhat expanded close to base, bearing a few slender spines at its tip, average length 232 microns, width 168 microns; thoracic spiracles

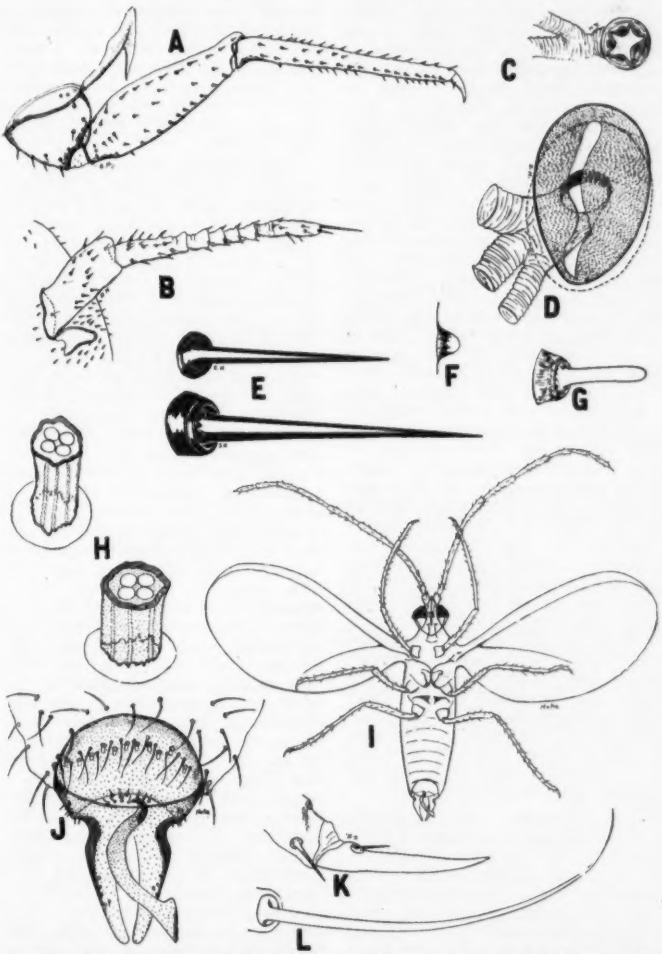


FIG. 40.—*Newsteadia americana:* A, adult female, leg, × 60; B, same, antennae, × 60; C, same, abdominal spiracle, × 650; D, same, thoracic spiracle, × 650; E, same, body setae, × 1,500; F, adult male, tubercle on apex of abdomen, × 1,500; G, same, spine from apical appendage, × 1,500; H, same, tubular pores from row near apex of abdomen, × 1,500; I, same, outline, × 20; J, same, apex of abdomen, × 230; K, same, tarsal claw, × 540; L, same, abdominal seta; × 1,500

not unusual, external opening a wavy, elongate slit, without spines, but with a few quadrilocular disk pores scattered around this opening; abdominal spiracles much smaller than the thoracic, external opening usually irregularly star-shaped, each accompanied by a number of quadrilocular disk pores, these spiracles occurring, so far as can be determined after a careful examination of available material, in 5 pairs, the 3 posterior pairs usually found in Orthezia apparently lacking in this species; derm with the quadrilocular disk type of pore only, these scattered over the body, but most abundant ventrally in the genital region, and dorsally in the spaces between the spine clusters, with smaller quadrilocular pores, set at the inner ends of tubular ducts, scattered through both the dorsal and ventral spine clusters; spiracles with a more or less distinct collar of irregular wax pores; derm ventrally with a transverse cluster of stout setae anterior to the genital opening, and a few additional elsewhere in connection with spine clusters; dorsally with a few such setae, usually in more or less definite relation to the clusters of spines; body spines in clusters dorsally and laterally, corresponding approximately in size and shape to the external secretion already described, ventrally in definite clusters surrounding the legs, antennae, and beak, and in a definite transverse band across the abdomen just behind the posterior legs (ovisac band), this continuing posteriorly at the margin for a short distance, finally fading out, not continued as a broad band completely encircling the ventral surface of the abdomen, as is usual in Orthezia; inclosed ventral surface of the abdomen without spines; anal ring of moderate size, with an outer row and an inner row of irregularly clustered pores, and 6 relatively short and stout setae.

LARVA.—Elongate oval, tapering somewhat posteriorly, average length as mounted 140 microns, width 86 microns; derm membranous except for appendages, and a transverse plate ventrally just anterior to the anal ring; antennae 4-segmented, the first stoutest, the last longest, and with an elongate terminal spine as in adult, each segment bearing a few setae and the terminal, in addition, bearing a curved fingerlike spine near base; legs not unusual, the fusion of segments as in adult; derm bearing numerous spines, these grouped into definite clusters approximately as indicated in figure; midventral longitudinal area entirely destitute of spines or of setae and the lateral ventral area with only narrow bands of setae; spines dorsally grouped into median transverse clusters on the head and thorax and into similar but shorter and bisected rows on the abdomen; abdominal spiracles present, minute, number not definitely determined; with a relatively large quadrilocular disk pore close to the opening of each; derm with an occasional quadrilocular disk pore, and with an occasional relatively large seta, the latter in definite relation to the spine groups; anal ring in general similar to that of adult.

ADULT MALE.—Small, elongate; total length 1.4 millimeters, width through thoracic region about 0.5 millimeter, length of antenna about 2.1 millimeters, length of wing 1.7 millimeters, width 0.9 millimeter; head strongly triangular in outline anteriorly, bearing a number of elongate slender hairs; compound eyes large, slightly protruding; with 2 ocelli, 1 behind and somewhat above the posterior outer angle of each compound eye; head broad behind the eyes, and nearly as wide as the distance through the eyes; antennae 9-segmented, the first 2 stout, the remainder very elongate linear and, excepting the 2 basal, bearing an apparently varying number of slender, threadlike setae, and in addition numbers of long, slender setae, these never in clusters or in any obviously definite arrangement, terminal segment with a stout, curved seta close to apex; legs elongate, slender, the trochanter distinctly set off from the femur, and the tibia and tarsus not fused as in other stages of the species, claw very long and slender, only slightly curved, digitules as in adult but more slender; legs bearing numbers of long, very slender setae on the basal half, these becoming stout on the apical one-half to one-third of the tibia and on the tarsus; wing broad, with only the costal thickening arising close to the base; halteres not observed; abdomen roughly parallel-sided, bearing transverse segmental rows of long slender setae, and an indeterminate number, apparently 5, of simple abdominal spiracles; with a single transverse band of stout, tubular ducts just anterior to the apex, and with very peculiar chitinized paired terminal appendages instead of the fused conical sheath present in most male coccids.

This species has been described from several mounted and unmounted adult females, larvae, and males from the Virginia shore of the Potomac River opposite Plummers Island, Maryland, under rotting logs and among trash,

collected by H. S. Barber, August 8, 1917 (holotype and paratypes); from the same locality, collected by H. S. Barber and Harold Morrison, June 15, 1922 (paratypes); and from Grimsby, Ontario, Canada, collected by Horn (paratype).

The types are in the United States National Collection of Coccidae.

NEWSTEADIA FLOCCOSA (DE GEER)

REFERENCE.—De Geer, 1778, Mem. Hist. Inst. 7: 604–605.

This species has been included in the key and the generic discussion on the basis of an examination of specimens of the adult female from England, Newstead coll., and from Loch Katrina, Scotland, among moss (Musci), coll. T. D. A. Cockerell, June 17, 1921. Published records include, in addition to the general localities given above, Australia (presumably accidentally introduced), Bohemia, France, Germany, and Sweden. The reported hosts are Cyperaceae, Glecoma (Labiatae), Gramineae, Helianthemum (Cistaceae), Luzula (Juncaceae), mosses (Musci), Sphagnum (Musci).

NEWSTEADIA TRISTANI (SILVESTRI)

REFERENCE.—Silvestri, 1924, Bol. R. Soc. Española Hist. Nat. 24: 174–176, figs. vii–ix (as Ortheziola).

Thanks to the numerous figures and extended description given by Doctor Silverstri, it is possible to reassign this form as the immature stage of some species of the genus Newsteadia. The external appearance, the number of abdominal spiracles, and the details of the body structure harmonize closely with the generic characters with the single exception of the number of antennal segments, and here it seems possible that the method of treatment for microscopic study may have influenced the appearance of the antennae, and that they actually have a greater number of segments than the three shown. The ventral ovisac band of the adult female is so striking a characteristic in all of the species in the subfamily that are positively known in this stage that it is hardly conceivable that the form described by Doctor Silvestri can be anything other than the preadult stage of some member of the genus. Certainly it can not be associated properly with either Ortheziola or Nipponorthezia.

No examples of this species have been available for study. It was described from San Jose, Costa Rica, where it was found in the ground in disintegrated vegetation.

GENUS MIXORTHEZIA, NEW GENUS

Adult female normally with plates of secretion in general resembling those of other genera, and with ovisac at maturity; body oval; antennae 4-segmented, the 2 terminal forming an elongate club; eyestalk small, irregularly conical, not fused to basal antennal segment; legs with tibia and tarsus fused in addition to coxa and trochanter, claw without denticles; beak elongate, 1-segmented; thoracic spiracles not unusual, abdominal occurring in 8 pairs as in Orthezia; derm pores quadrilocular, in 2 sizes, the larger often grouped in clusters of 2 to 5, the smaller at ends of tubular ducts; derm spines in bands and clusters as in other genera, but with the apices of each slightly enlarged and truncate; body setae relatively large and numerous; anal ring normal, with pores and 6 subequal setae; with a narrow, irregular, transverse thickening anterior to the anal ring dorsally.

Type of genus: Mixorthezia cubana, new species.

MIXORTHEZIA CUBANA, NEW SPECIES

Fig. 41

ADULT FEMALE.—All specimens alcoholic and the secretionary covering in consequence largely destroyed, but evidently consisting of flattened white wax plates corresponding in number and position to the clusters of spines and in general closely resembling those of other genera; ovisac probably shorter than the body; as mounted, oval, length 1.4 millimeters, width 0.9 millimeter; derm without chitinization except for a narrow transverse thickening, nearly obsolete across the middle line, just anterior to the anal ring; antennae normally 4-segmented, the first large, the second small, the last two forming a rather evident elongate club, apical spine long and relatively slender; eyestalk small, irregularly conical; legs not unusual, trochanter and femur completely fused, tibia and tarsus fused, but apparently with a division line indicated near the base of the combined part, claw long and slender, without denticles, tarsal digitules not differentiated from the spinelike setae present in rows on the part, claw digitules small, spinelike; beak well developed, length about 165 microns, width about 97 microns, 1-segmented; with the usual 2 pairs of thoracic spiracles, without spine collar around opening; with 8 pairs of short tubular, abdominal spiracles, the posterior pair on each side grouped as in

Orthezia; derm pores of the usual quadrilocular type, occurring singly, or frequently in clusters or strings of from 2 to 5, these pores relatively large and most numerous between the ends of the dorsal, marginal, and ventral spine bands; outer margin of ovisac band and anterior margins of transverse spine bands inclosed by ovisac band with a single row of much smaller quadrilocular disk pores set at inner ends of short tubular ducts; ovisac band with a scattered row of larger disk pores along outer margin of at least the anterior section; derm spines arranged in bands and clusters about as shown in figure, with 9 dorsal and 11 marginal groups on each side, the individual spines with very slightly swollen, more or less distinctly truncate apices; with a crowded cluster of small conical spines in the genital region; with the body setae relatively numerous and large, particularly in the ventral abdominal region; anal ring stout, nearly circular, with 6 setae and pores, but the exact character and arrangement of these not determinable from the material available.

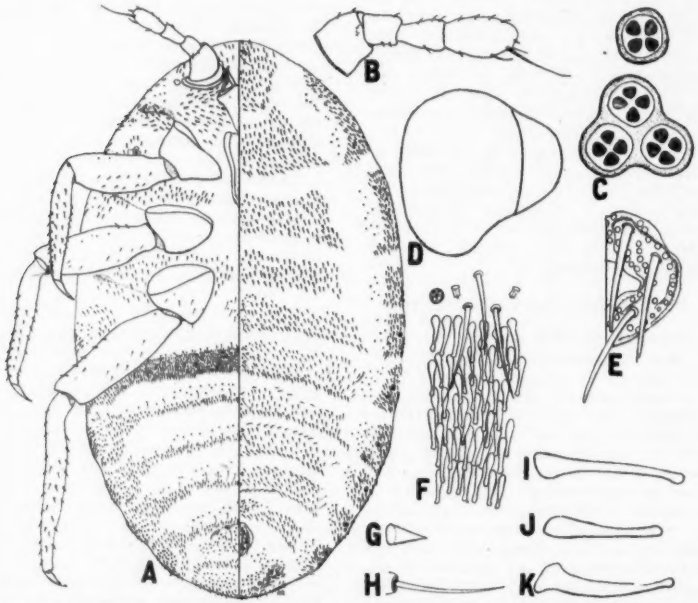


FIG. 41.—*Mixorthezia cubana*, adult female: A, body, dorsal and ventral, × 55; B, antenna (from preadult), × 115; C, quadrilocular disk pores, × 1,500; D, eyestalk, × 1,500; E, anal ring showing pores and setae (from preadult), × 500; F, section through anterior median portion of ovisac band, × 500; G, conical spine near posterior apex of body, × 1,500; H, body seta, × 500; I, dorsal spine, × 1,500; J, spine from ovisac band, × 1,500; K, spine from midventral abdominal area, × 1,500

PREADULT FEMALE.—Rather closely resembling the adult, except for the absence of the ovisac band and the reduction in the development of some of the structures associated with it.

No other stages have been available for examination.

The species has been described from two adult females, one mounted, the other unmounted, from four mounted preadult females, all collected at San Antonio do Sul, Oriente Province, Cuba, by Dr. W. M. Mann in 1920, and from another mounted immature female from Guantanamo, Oriente Province, Cuba, collected by Doctor Mann at approximately the same time.

The types are in the United States National Collection of Coccidae.

GENUS ORTHEZIOLA SULC

REFERENCE.—Sulc, 1894, Sitzber. K. Bohm. Ges. Wiss. 44: 1.

This genus may be characterized as follows as regards the adult female: External appearance of body in general resembling that of other genera of the subfamily; that is, bearing plates

of wax secretion and a definite posterior ovisac; body stout oval; antennae actually 3- but apparently 4-segmented, the terminal much the longest, the apical spine quite long and slender; apex of eyestalk cylindrical, its base apparently enlarged and forming a pseudobasal antennal segment; legs with tibio-tarsal articulation wanting, the parts fused, the leg setae spinelike, in distinct rows on tibiotarsus; beak 1-segmented, with a suggestion of a joint near base; each of the two pairs of thoracic spiracles opening in a spine cluster; abdominal spiracles not located in single specimen available for examination; derm pores mostly of the usual quadrilocular disk type, some in ventral region larger, apparently with 8 loculi; derm spines stout, swollen at bases and mostly distinctly capitate at apices, some, in a small cluster on each side of anal ring, but ventrally, oval in outline; body setae relatively large, but slender; anal ring with pores and 6 subequal setae; with a conspicuous transverse platelike thickening dorsally anterior to the anal ring.

While the appearance of the antennae gives a very distinct impression that each is 4-segmented, the actual fact seems to be that each eyestalk is enlarged laterally in the form of a short chitinized cylinder, or is fused to such a dermal cylinder, which supports the antenna. This conclusion is apparently verified by the fact that the small, double-walled circular to oval pore, probably sensory in function, which, in the writer's experience, occurs constantly on or close to the distal margin of the second antennal segment is, in this species, found on what appears to be the third antennal segment. Shortly after the first publication of the description of this genus Maskell advanced the view that there were actually 4 segments present rather than 3, as given in the description. Not long after this Sulc published a reply (in Bohemian), advancing additional reasons, apparently perfectly sound, for considering the proper number of segments to be 3, and this last discussion has been made available to the present writer through the kindness of Mr. James Zetek, of the Ancon, Canal Zone, laboratory of the Bureau of Entomology, who translated all of its essential parts into English.

ORTHEZIOLA FODIENS GIARD

REFERENCE.—Giard, 1897, Comp. Rend. Soc. Biol. [Paris] 10: 583–585.

This species was described from the island of Guadeloupe from the roots of a coffee tree. No specimens have been available for examination, and the characters given in the brief description are inadequate as a basis for comparing this species with the others discussed here.

ORTHEZIOLA VEJDOVSKYI SULC

REFERENCE.—Sulc, 1895, Sitzber. K. Bohm. Ges. Wiss. for 1894, No. 44, p. 2.

SYNONYM.—*O. signoreti* Haller (see Lindinger, 1912, Die Schildläuse, p. 373).

This species has been included in this paper on the basis of an examination of a single adult female, collected on rose bush from Malines, Belgium, at quarantine, Washington, D. C., by R. D. Kennedy, May 16, 1922 (F. H. B. No. 33632). It has also been recorded from Bohemia, England, Switzerland, and the Madeira Islands, either in ants' nests, from moss (Musci), or from grass roots (Gramineae), and it seems almost certain that the true host in the record given above was not the rose bush as recorded, but rather the moss used as packing around the rose plants.

GENUS NIPPONORTHESIA KUWANA

REFERENCE.—Kuwana, 1916, Annotationes Zoologicae Japonensis 9: 150.

SYNONYM.—*Orthezinella* Silvestri, 1924, Bol. R. Soc. Española Hist. Nat. 24: 170.

This genus may be given the following diagnosis for the adult female: Superficial appearance much as in other Ortheziinae, actually resembling *Orthezia insignis*, body stout oval, derm membranous, antennae plainly 3-segmented; legs with the tibio-tarsal joint only very faintly suggested, these parts fused solidly; beak distinctly 2-segmented, long, only slightly tapering; with the usual 2 pairs of thoracic spiracles and with 6 pairs of abdominal spiracles, the two posterior pairs wanting; derm pores mostly of the usual quadrilocular disk type, but some in the ventral abdominal area larger and with 6 loculi; body spines enlarged at bases, with apices almost truncate, but not swollen; body setae relatively large but slender; anal ring with pores and 6 short setae, with the intermediate pair conspicuously smaller than the others.

NIPPONORTHEZIA ARDISIAE KUWANA

REFERENCE.—Kuwana, 1916, Annotationes Zoologicae Japonensis 9: 150–152, pl. 4, figs. 13–23.

In addition to cotype specimens kindly forwarded to the Bureau of Entomology by the describer of the species and collected at Yokohama, Japan, on *Ardisia japonica* (Myrsinaceae), the writer has examined a single specimen from Brooksville, Fla., on root of *Lawsonia inermis* (Lythraceae) collected by L. V. Bottimer at quarantine, Washington, D. C., Mar. 27, 1924 (F. H. B. No. 49655) and several specimens from Rockville, Pa., in ants' nest, collected by F. M. Trimble, February 14, 1921 (No. 0–105).

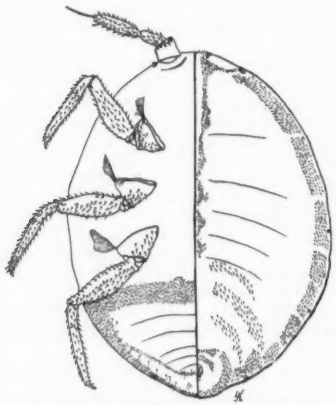


FIG. 42.—*Nipponorthezia ardisiae:* Adult female, body, dorsal and ventral; × about 25

The discovery of this curious coccid in the United States raises a question as to its probable native home, and as to whether it is as widely distributed naturally as *Orthezia cataphracta*. In a measure this discovery parallels the finding of another supposedly Japanese species, *Matsucoccus matsumurae* (Kuwana), apparently widely distributed through the Atlantic Coast region of this country. Until more is known regarding both of these species, this widespread and isolated distribution can hardly be looked upon as natural, and it suggests the possibility that the spread has been brought about through the movement of ornamental plants or nursery stock.

NIPPONORTHEZIA HISPANICA (SILVESTRI)

REFERENCE.—Silvestri, 1924, Bol. R. Soc. Española Hist. Nat. 24: 170–172, figs. i–iii (as Orthezinella).

If an exception be made of the single character of the number of antennal segments, then this species, as described by Doctor Silvestri, appears to agree closely with the genotype of Nipponorthezia in all generically important structural characters. Since neither the ovisac nor the ovisac band of spines is described or figured by Doctor Silvestri, it is evident that his specimens are preadult. It seems to the writer a possibility that the apparent division of the terminal portion of the antenna into 2 parts may be apparent only and due to some factor in the preservation and treatment of the specimens before study rather than to the actual presence of a joint. The species was described from Algeciras, Spain. No specimens have been available for examination.

NIPPONORTHEZIA NEOTROPICALIS (SILVESTRI)

REFERENCE.—Silvestri, 1924, Bol. R. Soc. Española Hist. Nat. 24: 172–174, figs. iv–vi (as Orthezinella).

The placing of this species in the genus Nipponorthezia is even less certain than was that of the preceding species, and it has been so placed largely because its describer considered it to be congeneric with *hispanica*.

The species was described from San José, Costa Rica. No specimens have been available for examination.

A TEST OF RAW ONIONS IN THE DIET AS A CONTROL MEASURE FOR WORMS IN DOGS[1]

By M. C. HALL, J. E. SHILLINGER, and E. B. CRAM, *Bureau of Animal Industry, United States Department of Agriculture*

INTRODUCTION

Recently, Blanchasal (*3*)[2] has recommended that as soon as pups are old enough to take any food other than mother's milk they be fed two to three raw onions in minced meat or in hard-boiled egg with bread and milk added to make a fine paste. According to him, onions are anthelmintic when used raw, but not when cooked. This idea that onions are anthelmintic is not confined to veterinary medicine. Wolff (*13*) has recently noted that at Paramaribo, in Dutch Guiana, the British-Indian population has a low incidence of ascarid infestation (35 per cent) as compared with that of the negro population (76 per cent) and that of the creole population (58 per cent), and the suggestion is made by him that this lessened incidence may be due to an anthelmintic action of the onions, garlic, and other herbs which enter into the diet of the British Indians. The antiquity of this belief may be judged from the statement of Khalil (*6*) that Avicenna (this name being the Latinized form of Ibn Sina), who was born in 981 and died in 1037, recommended garlic, among other things, for "long worms." As further evidence it may be noted from an article in the Hospital and Health Review (*2*), on "Folk Lore in Medicine," that in Brittany the peasants wear as a protection against worms an amulet composed of cloves of garlic threaded together lengthwise on an ordinary string. This is worn as a collar and its charm is believed to act both as a preventive and as a cure for worms. Onion clysters are commonly recommended for pinworms.

The idea that articles of diet may have anthelmintic value is widespread and has received more or less attention from medical men. In many cases there is practically no evidence given to support the belief, but in other instances there is some available evidence in regard to the value of certain substances. Diet has been reported as a factor in the control of pinworms. Recently Nyberg (*8*) has recommended the use of fresh blueberries for oxyuriasis. Adults and large children are advised to eat half a liter of the fresh berries three or four times during the first day and once a day as a meal for the next six days. His original article is not available and his evidence in support of the idea that the treatment is of value can not be cited. Lutz (*7*) advised in oxyuriasis the use of a diet which would give the smallest possible residue. Along the same lines, Stettiner (*11*) reported that he had treated one patient for pinworm infestation for years with never more than transient benefit until the patient developed diabetes and carbohydrates were excluded from the diet. Following this the pinworms disappeared. Subsequently, he used an antidiabetic diet as an adjuvant to the usual measures for pinworm infestation and had prompt cures in four cases under this treatment.

The use of sugars has been recommended for the control of certain worms. A writer in the Pastoral Review (Melbourne, Australia) (*1*), reports the passage of large numbers of worms by horses after being fed several handfuls of coarse brown sugar. Richards (*9*) reports that at the suggestion of an Indian hospital attendant he fed large amounts of raw sugar to patients infested with the Guinea worm, *Dracunculus medinensis*, and found that if this was continued for two days the worm usually came out on the third day, being wound out easily and without rupturing. The treatment was successful in all cases, the worms coming away in the course of a few days instead of several weeks. In connection with filarids it may be mentioned that Robertson (*10*) believes that pepper and piperine have prophylactic value in food and therapeutic value in the treatment of established cases.

[1] Received for publication May 19, 1924; issued April, 1925.
[2] Reference is made by number (italic) to "literature cited," p. 159.

That parasitism and metabolism are subjects with many factors in common has recently been emphasized by Hall (*5*), and it is evident that the transition from ordinary food to drugs is a gradual one, passing through such inorganic substances as water and sodium chloride to the various inorganic drugs, and through the various vegetable foods containing small amounts of essential oils, alkaloids or glucosids to these substances as derived from plants containing relatively large amounts. In the transition one encounters large numbers of substances having at least feeble anthelmintic power and some with considerable anthelmintic potency. Thus tobacco may be added to the feed of sheep or poultry and if suitably used may have some little anthelmintic value, and pumpkin seed has considerable efficacy in removing tapeworms. The possibility, therefore, that raw onions fed for a considerable period of time might prove to have some anthelmintic value is not altogether remote on theoretical grounds. Unfortunately, the recommendations of Blanchasal (*3*) left the case still based on theoretical grounds, so far as any definite scientific evidence of the value of onions is concerned, and did not advance the subject distinctly beyond the stage of the onion amulet.

EXPERIMENTAL DATA

To obtain definite evidence on this subject to replace or at least to supplement the speculations and theory of physicians and veterinarians, the writers conducted an experiment as follows: Four dogs were fed daily on what may be called an onion Hamburger steak made up to contain 2 oz. of raw onion, which was regarded as the equivalent of one onion of average size, ground up with 1 lb. of raw or cooked meat for each dog daily. The first feeding was on February 27, 1924, and the experiment was continued for 60 days. Early in April it was noted that the dogs were not cleaning up this amount of food, and beginning April 9, after 43 days on the previous ration, the amount of meat was cut in half, the amount of onion being left as before. One dog, No. 658, was found dead on the thirty-seventh day of the experiment; the other dogs survived through the 60-day period and were then killed. The feces of all animals were examined daily for worms passed, but the feces for Saturdays and Sundays were not always kept separate. In the following protocols the worms found in the feces are reported for consecutive days, failure to find worms is expressed by 0, failure to pass feces is expressed by a hyphen (-), and the combined record for a Saturday and Sunday is given in parentheses, to call attention to the fact that this represents a two-day period. The protocols, showing worms passed but ignoring tapeworm segments, are as follows:

Dog No. 654: 0; 1 whipworm; 0; 0; 1 whipworm; 1 whipworm; 0; 0; 0; 1 hookworm; (0); 0; 0; 0; 0; 0; -; 0; 0; 1 whipworm; -; -; 5 whipworms; (0); 0; 0; 0; 0; 0; (0); 3 whipworms; 1 whipworm; 0; 3 whipworms; 2 whipworms; 0; 1 whipworm; 3 whipworms; 0; 0; 0; 0; 0; 1 whipworm; 0: 0; 0; (1 whipworm); 0; 0; 0; 0; 0; (1 whipworm); 0. Total worms passed: 25 whipworms and 1 hookworm.

Dog No. 656: 1 whipworm; -; 0; -; 0; 7 whipworms; 1 hookworm; 1 whipworm; 0; 0; (0); 0; 0; 0; 0; 1 hookworm; 0; 0; 0; 0; -; 0; 0; (-); 0; 0; 0; 0; 0; (0); 0; 0; -; 0; 0; 0; 0; 0; 0; 0; 0; -; 0; 0; 0; -; (0); -; 0; 0; 0; 0; (0); 0. Total worms passed: 9 whipworms and 2 hookworms.

Dog No. 658: 0; 0; 0; 0; -; 0; -; 0; 1 ascarid; -; (0); -; 0; 0; -; 0; -; 0; 0; -; 0; 0; -; (0); -; 0; -; 0; -; (1 ascarid); -; -; -; 0. Total worms passed: 2 ascarids.

Dog 659: 1 whipworm; 0; 0; -; 1 whipworm, 1 ascarid; 4 whipworms; 0; -; 14 whipworms; (5 whipworms); -; 2 whipworms; 8 whipworms; 2 whipworms; -; 6 whipworms; 1 whipworm; 1 whipworm; 0; 1 whipworm; 6 whipworms; -; (1 whipworm); 0; 0; 0; 0; 0; (2 whipworms); 2 whipworms; 0; 0; 1 whipworm, 1 hookworm; 4 whipworms; 7 whipworms; -; 3 whipworms; 0; 1 whipworm; 1 whipworm; 9 whipworms; -; 0; 1 hookworm; 3 whipworms; 1 hookworm; (9 whipworms, 1 hookworm); -; 0; 1 whipworm, 1 hookworm; -; 0; 0; -; Total worms passed: 96 whipworms, 5 hookworms, and 1 ascarid. To this should be added 5 hookworms found in the large intestine postmortem, making a total of 10 hookworms passed.

These dogs, with the exception of the one (No. 658) which had died, were killed on the sixtieth day and examined for worms remaining. The findings for all dogs were as follows:

Dog No. 654: 314 whipworms, 20 hookworms, 74 *Dipylidium* sp. and 1 *Taenia* sp.

Dog No. 656: 2 whipworms, 18 hookworms, and 3 *Taenia* sp.

Dog. No. 658: 3 whipworms, 5 hookworms, and numerous *Dipylidium* sp.

Dog No. 659: 34 whipworms, 242 hookworms, and 3 *Dipylidium* sp.

From the number of whipworms passed during the course of the experiment it might be suspected that onions in the diet exerted an unfavorable

effect on these worms. On theoretical grounds this might be expected, if one assumes that the position of the whipworm in the cecum is such as to expose it to anthelmintic effects much less than in the cases of worms in the stomach and small intestines. We may assume that whipworms have little resistance to anthelmintics, as Hall has noted in a number of papers, since they are occasionally removed by relatively feeble anthelmintics if these drugs enter the cecum, assuming that their removal is due to establishing contact between the anthelmintic and the worms, and this low resistance may be correlated with the fact that many substances taken in by mouth are absorbed before reaching the ileo-colic or ileo-cecal valve, may be greatly diluted before they enter the cecum, or may pass into the colon without entering the cecum if they do reach the valve, in this way failing to establish contact or to establish it in adequate anthelmintic concentration. To arrive at more definite conclusions in regard to the effect of the onions on whipworms, one must compare the number passed with the number present post-mortem.

Dog. No. 654 passed 25 whipworms and had 314 post-mortem; passed 7 per cent.

Dog. No. 656 passed 9 whipworms and had 2 post-mortem; passed 82 per cent.

Dog No. 658 passed 0 whipworms and had 3 post-mortem on the thirty-seventh day; passed 0 per cent.

Dog No. 659 passed 96 whipworms and had 34 post-mortem; passed 74 per cent.

DISCUSSION

The figures show that these dogs passed 0, 7, 74 and 82 per cent of their whipworms while on an onion diet for 37 days in the case of 1 dog and 60 days in the case of 3 dogs, the lowest figure being for the dog on the diet for 37 days. In a general way one must conclude from these figures that a substance fed in such large amounts and for a period long enough to insure its entry into the cecum on many occasions, and then removes only 7 per cent of the worms in 60 days in the case of one dog, is not a very useful or effective anthelmintic. The dogs passed 130 out of 483 whipworms, or about 27.5 per cent.

Two other factors must be taken into consideration. One factor is that of possible mechanical anthelmintic action in one case. In the case of dog No. 659 which passed 74 per cent of its whipworms, the feces frequently contained large amounts of straw and hair and the passage of this coarse material was commonly accompanied by the passage of whipworms. The writers have often noted in fecal examination of dogs that whipworms commonly come away in the presence of hair, straw, excelsior and similar objects which appear to act as mechanical anthelmintics. Hall (*4*) has noted the passage of whipworms in connection with the passage of bots fed to dogs and believed that the bots acted as mechanical anthelmintics. From the fact that whipworms are apparently never found normally detached in the intestine the writers believe that these worms attach at a given point in their early development and never change this location. The larvae apparently penetrate the mucosa by means of a buccal lancet not present in the adult. If a mechanical anthelmintic detaches a whipworm it can not reattach; a whipworm detached is a whipworm lost. Dog No. 659 showed a pronounced pica, indicated by the presence of straw and hair in the feces and in the digestive tract post-mortem. This may be correlated more or less definitely with the heavy hookworm infestation, as pica is reported for human hookworm cases, notably in the case of the clay-eaters of the southern United States.

The other factor which must be considered is the possibility that the worms passed represented in part individuals which had lived out their lives and were coming away spontaneously and without regard to the onions or other possible anthelmintic factors. Parasitic worms in the digestive tract appear to live a year or less in many cases. Post-mortem examinations of many animals the world over has indicated that in the case of many worm species the number of worms increases in the late spring and through the summer, that the infestation may continue or increase into the fall, but that there is commonly a drop in the number present in late winter and early spring. In a very comprehensive study of tapeworm incidence in 2,012 horses, Stroh (*12*) found a seasonal incidence; thus *Anoplocephala perfoliata* was least abundant in spring and became increasingly abundant in the fall. It is well known that stomach worms in sheep become troublesome in the late spring and in the summer, but are much less troublesome in the fall and winter, and that sheep killed in the late winter and early spring will commonly show a much decreased infestation. The onion-feeding

experiment discussed here was conducted from February 28 to April 29, a period during which short-lived worms might be expected to pass out. The writers reserve judgment as to the fact in this case. Apparently little is known as to the length of life of whipworms. In anthelmintic experiments for the past 10 years the writers have not observed what they regard as the spontaneous passage of whipworms, but as they have rarely carried on experiments involving the examination of the feces of an animal for two months they have had little occasion to make observations on this point. Had they carried along some control animals in connection with this experiment more definite evidence on this point might have been secured. A microscopic examination of the worms passed during the last two weeks of the experiment showed a large percentage of males, and as males commonly do not live as long as females this finding suggested that these worms were passed spontaneously; of the female worms some were gravid females containing shelled eggs and others old females with no shelled eggs, the latter finding again suggesting that these worms had died of old age and were coming away spontaneously.

The case for hookworms is as follows:

Dog No. 654 passed 1 hookworm and had 20 post-mortem; passed 5 per cent.

Dog No. 656 passed 2 hookworms and had 18 post-mortem; passed 10 per cent.

Dog No. 658 passed 0 hookworm and had 5 post-mortem; passed 0 per cent.

Dog No. 659 passed 10 hookworms and had 242 post-mortem; passed 4 per cent.

These figures, 0, 4, 5, and 10 per cent, show the onions to have had little or no effect on hookworms. A microscopic examination of 3 hookworms passed during the last two weeks showed that 2 of them were males and 1 an old eggless female, all of which points to the probable spontaneous passage of these worms as a result of old age. The dogs passed 13 out of 298 whipworms, or about 4 per cent.

The case for ascarids is as follows: Dog No. 658 passed 2 ascarids and had none post-mortem; dog No. 659 passed 1 ascarid and had none post-mortem; no other dogs were infested with ascarids. The ascarids present came away on the fifth, ninth, and either thirty-second or thirty-third day. Owing to the light infestation here one can not draw any positive conclusion. One ascarid was an adult female, another a young ascarid; no careful examination of the third was made. One would be inclined to say that if onions were anthelmintic the human ascarid should have died out among certain races and nations where it has persisted, but on the other hand it might be urged that the human ascarid has become accustomed to and tolerant to onions, whereas the dog ascarid has had no occasion to develop such tolerance and might be susceptible to certain anthelmintic effects. The writers believe, however, that if feeding onions for 32 days is necessary to remove ascarids, the onion has too little anthelmintic value to warrant its use in view of the knowledge of better anthelmintics which would remove ascarids in less than that many hours.

So far as tapeworms are concerned, it is sufficient to say that three of the dogs had an infestation with *Dipylidium* sp. and two with *Taenia* sp., that the dogs continued to pass gravid segments during the course of the experiment, and that no tapeworms came away as a result of the onion diet.

SUMMARY AND CONCLUSIONS

Raw onions in amounts of 2 oz. daily to each of 3 dogs for 60 days and to 1 dog for 37 days showed too little anthelmintic value to warrant the use of onions as a control measure for worms in dogs. The writers are, therefore, unable to urge that: An onion a day keeps the worms away.

The use of onions was evidently of no value in removing hookworms or tapeworms. In spite of the passage of numerous whipworms, the nature of some of the worms passed and the factor of mechanical anthelmintic action in the case of the dog passing 74 per cent of its worms, suggests that the worms were passed partly as the result of their death from old age and partly from the action of mechanical anthelmintics. This idea is supported by the small percentage of whipworms passed by one dog and the failure of another dog to pass any. As regards ascarids it must be admitted that all the worms present (5) were passed during the course of the experiment, but the time required, up to 32 or 33 days, to remove an ascarid from one dog indicates that there is too little merit in the onion as an anthelmintic for dog ascarids to warrant its use.

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STUDY OF THE LIFE HISTORY AND ECOLOGIC RELATIONS OF THE SMUT OF MAIZE[1]

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INTRODUCTION

The smut of maize (*Ustilago zeae* (Beckm.) Unger) has proved much more difficult to control than any of the other cereal smuts. Although Arthur and Stuart (*2*)[3] believed they had obtained control by fungicidal sprays, it has been generally accepted that there is no known practicable method of control. Nevertheless, the current conception of the life history of the causal organism, drawn principally from Brefeld's classic investigations (*3, 4*), lends support to the idea that spraying might prevent the aerial conidia from producing infection. For this reason, further investigation of the ecology of the parasite, particularly with reference to the physiology and morphology of the host, has seemed necessary in an effort to develop methods of control. The investigations here reported cover the period from 1910 to 1920. Two brief abstracts have previously been published (*14, 18*).

Referring to experiments conducted in Kansas in 1896, Hitchcock and Norton (*8*) state, "the percentage of corn smut is here seen to rise to 26 per cent. This is, however, unusual; 6 per cent probably will represent the average." Selby and Hickman (*19*) reported as high as 25 to 45 per cent smut in limited areas of a cornfield in Ohio, but gave 4.4 per cent as the average infection. Pammel and Stewart (*15*) state that in Iowa only a fraction of 1 per cent of damage occurs for the entire state. In many Kansas fields, at the present time it is common to find 30 or 40 per cent of the plants affected with smut, while in the semiarid regions 60 to 80 per cent are frequently noted. These percentages are based on plainly visible nodal, sheath, ear, and tassel infections, and do not include the less important galls on the leaf blades. A few years ago a field was found in Nebraska which showed virtually every plant affected. Difficulties have been encountered by investigators in recording observations on corn-smut infection in percentages. It is apparent that the less conspicuous galls on the leaves and sheaths of the corn plant have been overlooked or disregarded by some, while other investigators may have included such infections in their reports. However, there appears to be sufficient reason for the belief that in the western part of the Corn Belt, at least, the disease has become much more prevalent during the last several decades.

NATURE OF INFECTION

Early observations made by the writers gave support to the statement of Pammel and Stewart (*15*) that the "lower nodes" are particularly subject to the disease and that on the same culm "where one smut boil made its appearance on the lower nodes, others appeared further up." A fair example of the data obtained on this point involves notes taken on 3,500 plants at Mitchell, Nebr., in 1914. Twenty-six per cent of these plants showed infection. This infection represented approximately 4 per cent of the buds on 3,500 plants, or 15 per cent of the buds on the infected plants.[4] Of this 15 per cent, 872 buds, or about 60 per cent of the infection, occurred on 372 plants, or 40 per cent of all plants showing any infection. In other words, 60 per cent of the total infection occurred on a little over 10 per cent of the total

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[2] The authors wish to express their appreciation for the assistance given by Ira Flemming and Ivan A. White during the course of these experiments.
[3] Reference is made by number (italic) to "Literature cited," p. 173.
[4] Counts were made to include 10 buds per plant, beginning at the bottom and counting upward to a point one bud above the ear.

number of the smutted plants, while the other 40 per cent occurred on 15 per cent of the smutted plants.

This tendency of infection to develop at more than one point on the same plant has been noted in numerous other instances (pl. 1). In 1913 a series of observations in eastern Kansas and Nebraska (and also at one point in Illinois) showed over 25 per cent of 581 infected plants to be smutted at more than one node. In the neighborhood of Washington, D. C., nearly 20 per cent of 78 plants were thus affected. In a field at Newton, Kans., in 1914, a very dry season, 15 per cent of the plants were infected and 36 per cent of the 95 infected plants were smutted at more than one node. At McPherson, Kans., with scarcely 5 per cent infection, about one-third of the smutted plants were similarly affected. At La Fox, Ill., of 58 smutted plants, 23 showed infection at two or more nodes. Again, in 1915, out of 324 smutted plants observed at points in Kansas and Indiana, over 30 per cent produced galls at more than one node. In addition to these, many hundreds of plants have been examined in the experimental plantings at Manhattan, Kans., with similar results.

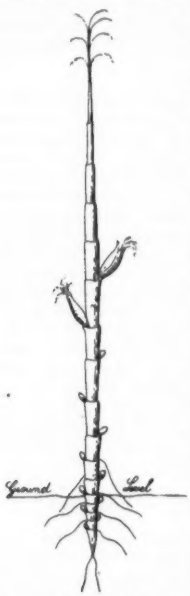


FIG. 1.—Schematic drawing of mature culm of maize, showing only those structures essential to an understanding of the presence of meristematic tissues. The apical "bud" bears several nodes with the staminate inflorescence at the tip. At about the fifth node down, the first lateral bud occurs, usually producing the pistillate inflorescence, or ear. Buds below this also may produce ears, depending on varietal characteristics and growth conditions. Toward the base of the plant the internodes are very short and buds beneath the ground level tend to develop into suckers, reproducing the structure of the parent culm. The lower buds may become infected and are sometimes mistaken for diseased "brace" roots, which are not often actually involved

Such data seemed inconsistent with the apparently well established ideas that corn smut develops its sorus only at the point of host contact and that infection arises from the mere chance of contact between aerial conidia and host plant. The fact that isolated nodal-bud infections are not entirely characteristic perhaps is not so easily explained unless it be supposed that the disease, in part at least, is systemic in character, as Pammel and Stewart (*15*) doubtless believed. Studies by the authors were begun, therefore, with the idea of checking all possible explanations of the problem presented.

THEORY OF SYSTEMIC INFECTION

The published data on the nature of corn-smut infection do not show an entirely clear conception of the development and morphology of the corn plant with relation to the occurrence of susceptible meristematic tissue. As shown by Brefeld (*4*), and more recently confirmed by Piemeisel (*16*), Pammel and Stewart (*15*) state that "the tendency to form smut boils increases in the lower nodes." Hitchcock and Norton (*8*) vaguely distinguish between infection of "rudimentary ears" and "nodes" but offer no further explanation. The number of nodal infections recorded in their table suggests that, for the most part, they should have been classified as rudimentary ears, because smutting of the true node itself is almost as rare as smutting of the internode. Arthur and Stuart (*2*) also appear to have overlooked the essential point, namely, that a bud exists at each of the lower nodes of the plant from the ear node down to the crown where the internodes become very short. Their division of the plant into "five aerial regions" is purely arbitrary. They illustrate (pl. 10, A) and record in Tables 49 to 52 the exceedingly common infection of these nodal buds as infections of the stalk or stem. MacMillan (*13*) apparently attributes the axillary infection to the presence of moisture in the sheaths rather than to the presence of meristem at the node.

MORPHOLOGY OF THE HOST

Because of the confusion which exists concerning the relation of smut infection to the structure of the corn plant, it seemed essential to clarify the conception of the morphology of the maize plant before attempting to analyze the problems of the etiology

of the disease or the relation of growth factors to the organism (fig. 1).

From the data published by Pammel and Stewart (*15*), Hitchcock and Norton (*8*, Table 3), and Arthur and Stuart (*2*, Tables 49 to 52, inclusive), as well as from the studies made by the writers, it is evident that the lower nodal buds or rudimentary pistillate inflorescences (ears) (pl. 1, D), are the most common points of infection. The foregoing additional evidence of a tendency for more than one of these buds to become infected on the same culm emphasizes the possibility of a systemic development of the disease under field conditions, despite the repeated evidence of inoculation experiments and the commonly accepted belief that the infection is strictly local in its development.

To begin with, the problem involves the possibility that if several sori appear on a plant they may have had a common origin. In this connection it should be recalled that only a comparatively short time, perhaps six to eight weeks, is required by the maize plant to develop from the stage in which the stem (morphologically speaking) is but a cone of tissue from 1 to 2 inches in length and largely in a meristematic condition, to that in which the various parts of the mature plant are differentiated and the stem has attained virtually its full height.

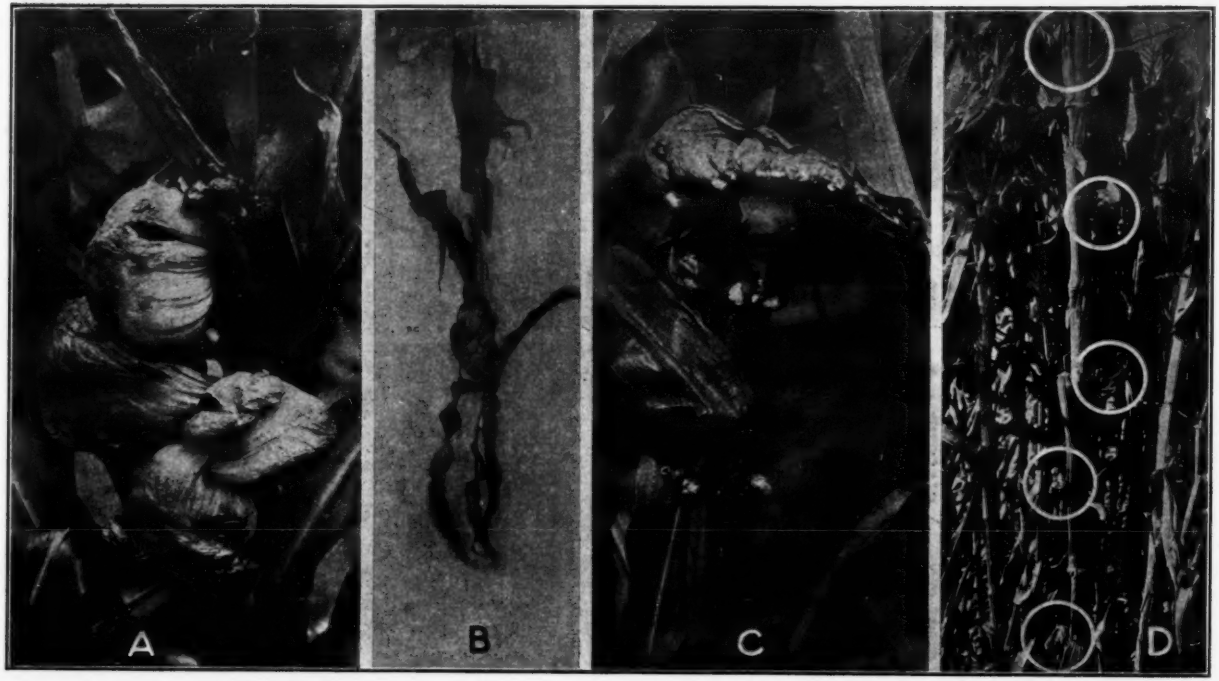
It need not be assumed, therefore, that because a plant showed several points of infection at the end of this period of rapid growth, these arose either from the growth of the parasitic hyphae from one point to another, or entirely from separate points of infection. It should be remembered that the incubation period for the smut organism in the field is generally 6 to 14 days, depending on environmental conditions. Therefore, full development and maturity of the sori would cover quite as much time as that required by the plant in growing from 1 to 2 feet in height. If, indeed, there had been but one primary infection to produce the several smut galls, it would have occurred at a time when there was but a small cone of meristem to be infected. The hyphae would have to spread only a very short distance in order to accomplish an infection in parts destined to be widely separated in the mature plant.

Brefeld has shown that corn smut may produce sori in any young tissue and that the organism does not spread from the point of infection. But neither do any of the admittedly systemic cereal smuts spread through the host tissues to any great extent. The distribution of the parasite in all such instances is brought about by the host itself when the culm or culms develop. The problem in the present instance, therefore, is to determine the reaction between the host and parasite, rather than the capacity of the parasite to penetrate the developing tissues of the host.

INFECTION STUDIES

That the relation between the host and parasite under field conditions is not one of true systemic development of the disease has become convincingly evident from the data of Pammel and Stewart (*15*), Hitchcock and Norton (*8*), Arthur and Stuart (*2*), Piemeisel (*16*), and several others, all of whom confirm Brefeld's original conclusions. The writers also have repeated extensively similar experiments with numerous variations based on the idea that *Ustilago zeae* might be found to resemble somewhat the head smut of sorghum, *Sorosporium reilianum* (Kühn.) McAlp. (*17*), which attacks both sorghum and maize (*11*, *12*). This species develops systemically in sorghum from an infection occurring later than the very early seedling stage. In this respect it resembles the "Triebinfektion" of *Ustilago violacea* (Pers.) Fckl., as noted by Hecke (*6*). However, all attempts thus far have failed to produce any evidence of systemic infection in corn smut.

Similarly, efforts to protect seedlings and young corn plants from infection have not succeeded in altering the frequency or nature of infection of plants in the field. This work has involved both chemical and thermal disinfection methods for seed and soil, as well as attempts to protect young plants from infection by careful disinfection of the seed, sterilizing the soil, and starting growth in the laboratory and in cloth-covered beds. Notes were taken on about 9,000 plants, including controls, at Manhattan, Kans., St. Paul, Minn., and Mitchell, Nebr. The lack of satisfactory methods for absolutely excluding infection and controlling other conditions, however, marred the conclusiveness of the negative results obtained. Nevertheless, the data are in accord with the results of other investigators, in leading to the conclusion that true systematic infection is not involved.



Ecological Relation of the Smut of Maize

(For explanatory legend see page 165)

Plate I

(For explanatory legend see page 165)

RELATION OF WEATHER CONDITIONS TO INFECTION

Inasmuch as the results of seed and soil treatments and inoculations have disclosed nothing to indicate true systematic development of the disease under field conditions, a more intimate understanding of the relation of weather conditions to the smut fungus and its ability to infect its host seemed necessary to an interpretation and explanation of the characteristic nodal-bud infection.

Arthur and Stuart (*2*) have elaborated meteorological observations covering a season in an attempt to demonstrate the close relationship of humid conditions to infection by the corn-smut fungus in the field. Although Piemiesel (*16*) has shown that the conidia are very resistant to desiccation, he seems to have accepted the conception of the dependence of infection on high humidities. Similarly, MacMillan (*13*) emphasizes moisture as a possible limiting factor in arid regions.

These prevailing ideas are not in accord with the fact that the disease is not peculiarly prevalent in humid areas and under humid conditions. According to the writers' observations corn smut appears to be far more abundant and destructive in the extreme western portion of the Corn Belt, in the dry hot portions of the plains of Kansas and Nebraska, than it is in the humid districts of the Eastern States. Selby and Hickman (*19*) also have observed that "more smut is found in dry seasons than in wet seasons; the same appears to hold as to situations." While this fact does not obviate the necessary relation of moisture to infection, it does appear to minimize its importance as a limiting factor in the distribution and prevalence of the parasite under field conditions.

The observations of Hitchcock and Norton (*8*) on ecological relations seem the most adequate thus far offered. They conclude, as a result of their experiments, that infection "does not depend so much on the time of the season as on the stage of development of the plant." They point out that in seasonal succession the leaves, tassels, ears, and lower nodal buds become the principal areas for smut infection, because in the development of the plant they are successively exposed in the meristematic condition. If, then, there are successive "outbreaks" of the disease, as observed by Arthur and Stuart (*2*), and more recently by Piemeisel, (*16*), it would, perhaps, be more logical to attribute these to the effect of such conditions upon the development of the host rather than to any effect upon the parasite, or, perhaps, merely to the coincidence of the condition of the host and the "frequent rains and cooler weather" of late summer (*16*). Such a season came under observation in Kansas in 1920 when the cooler weather and frequent rains in August had a stimulating effect on the growth of the corn crop accompanied by an apparent late infection of smut.

To summarize, it appears exceedingly doubtful, particularly as to infection in the ears or nodal buds, whether moisture can be considered in any material degree a limiting factor in smut development under such climatic conditions as are required for the maturity of maize.

ECOLOGIC STUDIES

Under conditions generally suited to maize culture, mainly at Manhattan, Kans., the writers began a series of investigations to determine the presence of the smut organism on the maize plant or in its environment, previous to the development or appearance of the smut. These were supplemented by attempts to shield the plants from infection, including the seed and soil treatments and the fungicidal sprays herein described.

Efforts to isolate cultures of *Ustilago zeae* from the cornfield, prior to the earliest sporulation, naturally assumed three different aspects, namely, cultures from the soil, from the air, and from the plants themselves. (See Table I.)

In order to bring the nature of this work more clearly before the reader, the history of several individual isolations (cultures) which proved virulent in the production of the disease are traced out in all the details of manipulation.

EXPLANATORY LEGEND FOR PLATE 1

A.—A plant inoculated with hypodermic needle on June 7, 1918, using culture No. 6c, isolated in 1917 and carried over on carrot agar until 1918. Smut galls evident June 18, 1918.

B.—A plant infected from the same culture, showing large smut gall at point of inoculation.

C.—A plant inoculated by means of a hypodermic needle, June 22, 1918, with culture No. 79 carried over from 1917. Smut galls evident July 2, 1918.

D.—Pseudosystemic (nodal bud) infection developed on a culm of pod corn (*Zeae maydis* var. *tunicata*). Some of the (nodal bud) infections do not show in the photograph. Note that neighboring stalks are smut-free.

TABLE I.—*Isolation and infection results obtained from several collections of the corn smut organism, Ustilago zeae, in experiments conducted at Manhattan, Kans., 1916 to 1919, inclusive*

Year	Collections			Inoculations			
	Source	Total number	*U. zeae* in culture plate [a]	Number of isolations (cultures) used	Number of trials	Infections produced	Cultures found virulent
1916	Soil [b]	15	1	Lost.			
1916	Air	43	24	3	6	1(?)	1(?)
1917	do	73	18	2	10	1	1
1918	do	301	87	44	165	14	12
1919	do	150	58	32	369	70	24
1916	Plant leaf axil	71	37	5	27	9	1
1917	do	84	39	13	120	11	6
1918	do	162	53	111	369	41	37
1919	do	103	25	20	213	15	8

[a] Some of these microscopic identifications are necessarily uncertain, because of the occurrence of yeast-like cultures and their similarity to those of the smut fungus and the impossibility of isolation for adequate study because of contaminations.

[b] Isolations from soil proved very difficult because of the large number of other organisms capable of more rapid growth. In more recent work isolations from the soil have been successful.

Culture No. L 44c was isolated on June 14, 1916, when the plant was about 1 foot high. With a specially made sterile pipette, about 1 cc. of liquid was drawn from the axil of one of the upper leaves of plant No. 44 in row "L" of the experimental plat.

Immediately after drawing the liquid from the leaf axil of a plant it was placed in a sterilized tube, taken to the laboratory, and plated out in carrot agar. These plates were kept at from 20° to 23° C. Five days later, three colonies of *Ustilago zeae* (designated hereafter as L 44a, L 44b, and L 44c) were noted in the plate in the midst of other fungous and bacterial growth. These colonies had been identified a few days earlier under the microscope (low magnification) by the characteristic "snowflake" appearance. Plate 3, A and B, shows a photomicrograph of two colonies from culture plate No. L 44c, with similar colonies, C and D, from a known culture of corn smut for comparison. Because of the slow development of the smut colonies as compared with the contaminations in the culture plate, it was necessary to remove them as soon as possible. This was done by ringing the colonies, waiting a few days until they became visible to the naked eye (about 0.1 to 0.2 mm. in diameter), and then removing the colony by means of a flat platinum wire (*9*), taking pains to leave a bit of the agar surrounding the fungous growth.

The characteristic gray-white color and "stringy" consistency of the fungous mass in the culture medium in the early stages of growth made it possible in subsequent studies to isolate the colonies without preliminary microscopic identification (pl. 3, D). It was found also that contamination by bacteria could be largely eliminated by adding two ot three drops of a 5 per cent solution of lactic acid to 10 cc. of the carrot agar. This did not inhibit the growth of the smut fungus.

Cultures of *Ustilago zeae* show a greater tendency to hyphal or mold-like growth than do those of head smut of maize and sorghum, *Sorosporium reilianum*. In old cultures this frequently appears as a whitish pubescence over the surface of the growth, or the white hyphae are noticeable at the margins of the cultures. This characteristic does not seem to be dependent entirely upon the age of the culture after transfer but, to some extent, at least, upon its age from the time of spore germination. This has been most commonly noted on carrot agar. Generally after transfer the colony darkens gradually through tan, brown, or olive, unt l almost black, the exact appearance being affected by the hyphal development which seems inclined to occur in spots over the usually rugose surface of the growth. In old cultures the consistency becomes almost leathery; somewhat like the fruiting body in the Hymenomycetes.

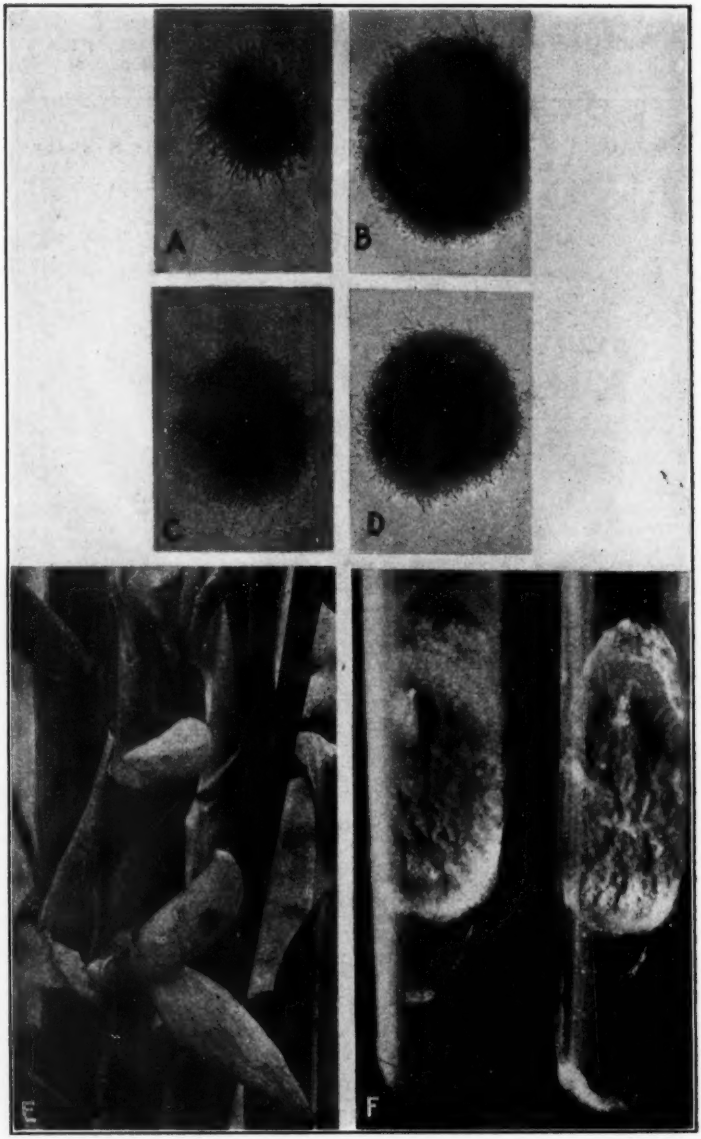
Having determined by the cultural characteristics above described that the three isolations, a, b, and c, obtained from the plating of No. L 44, corresponded to cultures of corn smut, an effort was made to verify this identification by using them in inoculations. Transfers were made to tubes

Ecological Relations of the Smut of Maize. **Plate 2**

Culture L 44c was used in producing these infections.

A.—Infection produced by allowing a mixture of 2 cc.culture decoction and 5 cc. distilled water to trickle down into the leaf axils. This was poured into the top of the plant. Not all of the smut lesions are shown in the illustration; arrows indicate visible sori.

B.—Infection resulting from injection of liquid culture by means of a hypodermic needle.



Ecological Relations of the Smut of Maize. Plate 3

Figs. A, B, C, and D, photomicrographs of colonies of *Ustilago zeae* on carrot agar plates, two days old from conidial sowing at 20° to 22° C. × about 100.

A.—Small colony, isolation L 44c.

B.—Large colony, isolation L 44c.

C.—Small colony, single spore (chlamydospore) isolation of *Ustilago zeae* for comparison with A.

D.—Large colony of *U. zeae* (from chlamydospore) for comparison with B.

Figs. E and F.—Photographs about one-half natural size.

E.—Plant inoculated with culture No. 88, in the same manner as described for cultures Nos. 6c and 79 in legend of Plate 4.

F.—Cultures of *U. zeae*. Note the rugose surface.

of carrot decoction which were allowed to incubate at 23° to 25° C. for two or three days, until the culture appeared turbid and sometimes covered with a thin scum of aerial conidia. These liquid cultures were used to inoculate young plants either by pouring them into the leaf axils, or by injecting them into the region of the growing point (6 or 10 inches from the ground in plants 12 to 18 inches high) by the use of a hypodermic needle. Of the three isolations, all of which were used in numerous inoculations, No. L 44c alone gave positive results, producing smut in almost every trial. Plate 2 well illustrates its virulence.

Isolations Nos. 6c, 79, and 88 were made in 1917 and may be taken as typical examples of virulent cultures. Continuously growing them on artificial media did not seem to reduce their virulence when used for inoculation.

Culture No. 6c was isolated as described for No. L 44c, from the topmost leaf axil of a plant 5 inches tall. Three isolations taken from this same agar plate proved virulent. The results of an inoculation with "6c" are shown in Plate 7, A, B, and C.

Culture No. 79 was isolated by using photographer's porcelain developing trays containing a small quantity of distilled water and having a surface 5½ by 8 inches. These were exposed for 16 hours in the cornfield. Of the 12 cc. of liquid recovered from the water plate, one-third was used in pouring the agar plate for isolations. Numerous colonies appeared in the plate. One was isolated and proved virulent in a number of trials (pl. 7, C).

Culture No. 88 was isolated the latter part of July from the axil of the ninth leaf of a fully developed corn plant. This proved virulent in several trials in both 1917 and 1918 (pl. 3, E).

From Table I, it will be noted that the isolation of cultures which seemed to be morphologically identical with those of *Ustilago zeae* was accomplished frequently and with little difficulty. In many cases, however, there remained some doubt as to the identity of such cultures, because the smuts in artificial culture or as young colonies closely resemble numerous yeasts and other somewhat similar organisms. The fact that many of the cultures proved virulently pathogenic leads to the belief that others also may have been pure cultures of *U. zeae*, although no infections were obtained. Such an assumption is supported by the coincident failure of virulence in known cultures originally made from a single chlamydospore of *U. zeae*. The plants used for inoculation were grown from seed of open-pollinated ears. This undoubtedly could explain part of the irregularities obtained in such inoculations, and is supported by results of experiments now being conducted in Kansas to determine relative resistance of inbred strains of corn to smut.

The nature of the infection, also is pertinent in such cases as those noted by Pammel and Stewart if we may but alter their statement to read, "where one smut boil made its appearance on the *upper* nodes others appeared farther *down*." In other words, it would seem that such infections frequently arise from one and the same contamination of axillary moisture by *Ustilago zeae* at a relatively early period in the plant's development. This axillary culture then spreads by running down into the lower axils. This view of axillary contamination has appealed also to Arthur and Stuart (*2*), except that they do not trace the several galls to the same contamination, nor have they evidence that *U. zeae* ever was present in the leaf axils. The writers have produced such infections by artificial inoculation, an example of which is seen in Plate 2, A.

At the beginning of these investigations the point which appealed to the writers as most pertinent to the problem of fungicidal control was the probability that aerial conidia falling upon the corn plant produce direct local infection only in some instances. Susceptible tissues of the host are seldom exposed to direct attack, except perhaps by some injury (*7*), so that in the normal course of events an interval must occur between the contact of the conidium with the host and actual infection of the tissues. In this respect *Ustilago zeae* may be considered as distinct from other more highly specialized parasites among the cereal smuts, most of these being capable of infecting only the very young seedlings. The latter necessarily have to enter their hosts in the seedling stage if they are to infect at all.

Corn smut, on the other hand, may be considered frequently pseudosystemic in its attack, as it appears to exist *on* the host rather than *in* it prior to the development of the disease in its most typical form in the nodal buds or ears. This fact is of interest in view of the positive statement of Arthur and Stuart (*2*) that fungicidal sprays gave definite indication of control. The writers, therefore, have attempted similar treatment with several variations, not so much with the idea of any immediate practical importance which

might result from such spraying experiments, as to obtain confirmatory evidence in the study of the ecologic factors affecting the development of the corn-smut organism. These results are briefly described below.

THE POSSIBILITIES OF CONTROL

In attempting a study of control measures, the following three general lines of procedure suggested themselves, namely, fungicidal treatments, cultural methods, and the development of resistant strains or varieties of corn.

FUNGICIDAL SPRAYS

The only experiments with fungicidal sprays which had been conducted up to 1910 when these investigations were begun, were those by Kellerman (*10*) in Kansas, and Stuart (*20*) and Arthur and Stuart (*1*) in Indiana. These early investigations, however, were not extensive and no record was made of the significance of the effect of the sprays on the corn crop, particularly the yield.

In the spraying experiments conducted by the writers, approximately 13,000 plants were used during the several seasons in which the work was done at Manhattan. (See fig. 2.) The yield of grain per plant always *increases with* the percentage of smut found in the plant. In other words, the effect of the fungicides has been to decrease not only the smut but also the yield. The figures on yield may be accepted as a measure of the general reduction in vegetative vigor due to injury done by spraying. It seems therefore, that an adequate interpretation of these data, which obviously give a distinct indication of smut control, must give due consideration to the host injury occasioned. Arthur and Stuart (*2*) noted some such injury in their experiments and, as in the work at Manhattan, were not successful in attaining complete control. Their conclusion, however, that true fungicidal control had been attained would seem hardly to be justified by the mere fact of reduction in infection percentages. Plants which have been so definitely reduced in vegetative vigor would necessarily produce less meristematic tissue, a circumstance which involves a correspondingly lessened production of smutted tissues.

In order to understand the spraying results at Manhattan, Kans., it seems sufficient to present only briefly the formulas of the sprays used. The Bordeaux mixture sprays were: 6–4–50, 4–5–50, 3–4–50, 1–1–50, and the lime-sulphur solutions were 1 part of the concentrate to 30 or 40 parts of water. Formaldehyde solutions of the strength 0.1 and 0.2 per cent were used, and during one season $CuSo_4$, one part to 100 of water, was tried.

In support of the conclusion that true fungicidal control is doubtful, may be mentioned the fact that both conidia and chlamydospores will germinate on glass slides sprayed with certain strengths of Bordeaux mixture, copper sulphate, and lime-sulphur. Similar observations have also been made by Dandeno (*5*). The writers have made no effort to analyze the many complications involved in comparing these laboratory germinations with results obtained from the use of these fungicides in the field. It is only desired to present here the observation corroborating the conclusion that it is very questionable whether real fungicidal effect has been attained in any attempts to control corn smut by spraying.

The efforts to prevent infection having yielded essentially negative results, it would appear desirable to note the points on which further research might yield results and indicate the lines of procedure for developing possible control measures. Since it has been shown that the smut fungus exists in an active virulent condition in the leaf axils of corn in the field, it appears possible that some way might be found for suppressing such virulence, even though the culture actually can not be killed without injury to the host. Piemeisel (*16*) has shown that virulence may be retained for some time in artificial culture. The experience of the writer substantiates this, but since some cultures apparently lose the power to infect, it seems more pertinent to the problem of control to discover when and why virulence is lost. If the answer to this question discloses no feature which could be put to practical use in controlling the disease, there still remains a possibility that methods of applying chemical dusts or even of other sprays may be developed which will avoid injuring the plant. This must be accomplished before satisfactory observations of control can be made, and probably will necessitate trials with other chemicals than the fungicides commonly used as liquid sprays.

DATE OF PLANTING

Studies have been made during several seasons on the effect of the date of

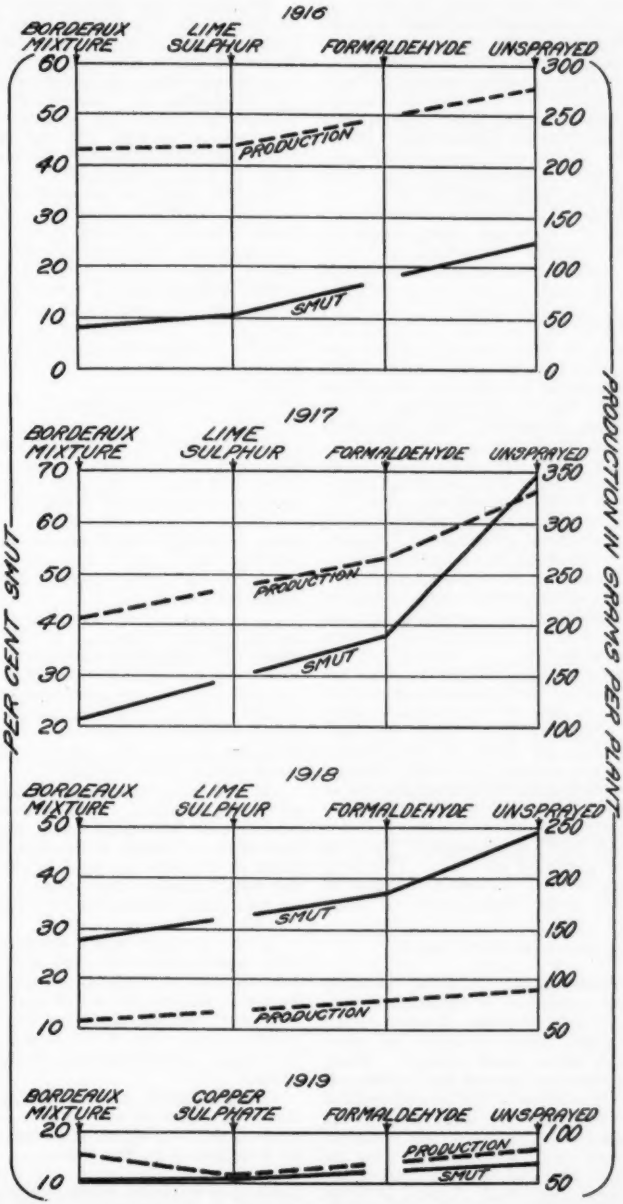


FIG. 2.—Graphic representation of production (weight of ears) per plant and percentage of smut in sprayed and unsprayed plats in four successive seasons, 1916 to 1919 inclusive, at Manhattan, Kans. Where the curves are broken at aperpendicular, it is indicated that data on that chemical were not obtained in that year. Commercial white corn was used in these experiments

planting the corn upon infection by smut. It was believed that ecologic information on the prevalence of conidial distribution of the organism might be gained by planting certain varieties at successive dates during the season. The varieties used were Kansas Sunflower, Hildreth's Yellow Dent, Boone County White, and Commercial White. They were planted, in so far as possible, on April 15, May 1 and 15, June 1 and 15, and July 1, in the years 1915 to 1918 inclusive.[5] Plantings were made at Manhattan and Hays, Kans. The results seemed to show less infection in plantings made on June 15 and July 1 than in earlier plantings. This might be due to the fact that fewer conidia occurred at the critical period of infection for these late plantings and that environmental conditions were less favorable for the development of the organism. However, the plantings made on July 1 were always only in the tasseling stage when the first killing frost occurred. This relative immaturity of the host would also affect the extent to which the plants developed visible evidence of infection. Apparently, no evidence can be adduced from these results which would warrant conclusions of ecologic value. Experiments now being conducted by the junior author, in which strains of corn homozygous for the character of resistance and susceptibility to smut are being used for dates of planting, will no doubt give data of value on this point. Observations, however (these data are summarized by years in the inoculation results in Table I), have indicated the increasing prevalence of conidia in the cornfield as the season advances. It is impossible to escape this increase by early planting because of the long growing period of the crop. The early planting of early-maturing varieties, as of sweet corn, might prove of some value.

VARIETAL RESISTANCE

Experiments to discover possible varietal resistance to corn smut were made with 25 varieties of maize in the three years 1916 to 1918 inclusive. Negative results were obtained. None of the varieties showed any consistent behavior relative to the development of smut infection, the differences being insignificant and more or less variable. Hitchcock and Norton (*8*), after an extensive series of tests in 1894–1895, also concluded that "there is little difference in varieties of corn as to their susceptibility to smut."

Because of the heterozygous nature of the corn plant, these essentially negative results might have been anticipated. However, judging from the experiments which are being conducted at Manhattan at present, it seems possible to expect that in many varieties, inbred strains may be secured which will vary from complete susceptibility to marked resistance.

Furthermore, the problem of breeding for resistance may become still more complex if specialized forms of the organism are found to exist in different localities (*14*). In such an event, it would have a very significant bearing on the program of breeding for resistance. This phase of the work is being investigated by the junior author at the present time.

SUMMARY

(1) Corn smut is widespread throughout the Corn Belt and is becoming an important limiting factor in corn production in regions of relatively scant rainfall. Owing to the nature of corn smut infection it has been found impossible to control the disease by methods commonly applied to other cereal smuts.

(2) A clear conception of the development and morphology of the maize plant with relation to the occurrence of meristem susceptible to infection, is requisite to an adequate interpretation of the field phenomena which often simulate systemic infection. The rudimentary ears of the lower nodes are most commonly involved.

(3) Neither inoculation studies nor attempts to shield young plants from infection in the field have produced evidence to indicate systemic development of *Ustilago zeae* in corn plants in the field. Earlier observations bearing on this point, therefore, are fully confirmed.

(4) An ecologic study covering four crop seasons has indicated that moisture is not a limiting or controlling factor in the occurrence of corn smut, and that infection does not depend so much on the time of the season as on the stage of development of the host plant.

(5) The aerial conidia falling upon the corn plant do not appear to produce direct local infection so frequently as is indicated by the literature on the life history of corn smut. A common method of infection is the development of a virulent culture in moisture held in the axil of a leaf of a young plant.

[5] The data at Manhattan, Kans., were obtained from the plots grown by the Department of Entomology of the Kansas Experiment Station.

Such a local culture is likely to produce other infections in adjoining nodal tissues and thus produce a pseudosystemic development of the disease.

(6) Apparent partial smut control with fungicidal sprays has been shown to be due to host injury by the spray, resulting in a reduced vegetative activity, a circumstance which involves a correspondingly lessened production of smutted tissues. Wherever the smut was lessened by fungicides, a similar reduction in yield occurred.

(7) Planting numerous varieties of corn on several successive dates in an attempt to avoid infection gave only negative results.

(8) Strains of corn can be secured by inbreeding which show great variations in susceptibility and resistance to smut. Their behavior in different regions is being studied in an attempt to discover whether a difference may exist in the corn-smut organism. This phase of the problem is now being studied at Manhattan, Kans.

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FURTHER STUDIES ON THE TOXICITY OF JUICE EXTRACTED FROM SUCCULENT ONION SCALES[1]

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SCOPE OF THE INVESTIGATION

In a previous paper reporting studies on the nature of resistance to onion smudge, the senior author (*7*)[2] has discussed the toxicity of volatile substances of the host to the causal fungus, *Colletotrichum circinans* (Berk.) Vogl. It was pointed out at the time that, although these substances did not apparently contribute to the conspicuous varietal resistance of highly pigmented, as compared with unpigmented, varieties of onions studied, they probably did play a rôle in restricting the parasitism of the organism. The obvious question arose during the course of these studies as to the effect of these volatile substances upon other parasites of the onion bulb. As one approaches these fundamental questions of parasitism the complexities become increasingly apparent. The interrelations with the host are probably specific for each parasite. Each invader attacks by its own method and the defense of the host may in each case be different. The present investigation was undertaken primarily with the idea of throwing further light, if possible, on the general question of parasitism.

In this work the crude mixture of volatile substances arising from onion tissues, usually after crushing, was used. It is often erroneously stated in textbooks that the chief volatile constituent of the onion is allyl sulphide ($(C_3H_5)_2S$). Semmler (*4*), however, found that the volatile oil from onion contains no allyl sulphide, but is made up principally of a disulphide, $C_6H_{12}S_2$. It also contains a higher sulphide of the same radicle and another sulphur-containing compound which is probably identical with one of the higher-boiling asafetida oils. Since any attempt at isolation of the individual substances is likely to alter considerably the complex as it exists in the plant, it was considered best for the purpose of this investigation to study first their combined effect upon the fungi. In considering the results, therefore, it is evident that one or more compounds may be responsible for the toxic effects observed.

It is of interest to note that since the completion of the senior author's last paper (*7*), Brown (*2*) has published his studies on the effect of volatile substances from various plant parts upon spore germination. He notes a stimulating effect in the case of most tissues tried, but when onion tissue was used marked inhibition was found to occur. Brown also points out that in an ordinary moist chamber, formed by placing moist filter paper in the bottom of a closed dish, there is a biotic reaction which results in the fermentation of the filter paper and this process yields a volatile substance toxic to the fungi which he studied. He did not find this to occur, however, until several days after the filter paper was moistened. Since all of the writers' observations were made within 24 hours after initiation of the experiment, and since all experiments were controlled, they do not consider that this factor has entered into the results. With the method of experimentation used it was impossible to duplicate actual conditions which the parasite encounters upon entering the host tissue. It is quite probable that the volatile substances released upon crushing the tissue do not occur thus exactly as they existed in the host cell. The manner in which the fungus is exposed to the onion oil may differ widely as between the experiment and nature. Many of the bulb parasites

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[2] Reference is made by number (italic) to literature cited, p. 87.

alter the host tissue in advance of the hyphae, and in that process part or all of the toxic substances may be changed or rendered inactive. These facts naturally limit the value of the experimental data in answering finally many of the questions which arise in connection with parasitism.

In order to reduce to a minimum the influence of outside factors upon the results the procedure was standardized as much as possible. This involved a study of the relation of temperature, age of spores, and age and condition of bulbs to the toxic effects of the volatile substances. Having worked out these relations primarily with a single fungus (*Colletotrichum circinans*), the comparative study of a number of fungi was begun.

METHODS

The volatile substances were obtained from onion juice which was secured by grating the succulent onion bulb tissue, placing it on a dry filter paper, and allowing it to filter without pressure. In certain cases, when a large amount of liquid was desired, the grated pulp was first placed in cheesecloth and the juice pressed out before filtering. No appreciable difference in the toxicity of extracts obtained by the two methods was noted, but to avoid any possible variation due to this cause, a single method was used throughout any given experiment.

A spore suspension of the fungus in question was made in sterile nutrient liquid, either potato or onion decoction. Drops of the spore suspension were placed on a glass slide in a moist chamber. Another slide containing one or more drops, as needed, of the expressed onion juice, was placed in the same chamber. Control chambers without onion juice were always included in the tests. In all these experiments Petri dishes of uniform size, lined with moistened filter paper, were used as moist chambers and definite amounts of expressed onion juice were used as sources of the volatile substances.

Observations were made after 6 to 24 hours, depending upon the rate of germination and growth of the fungus in question. In order to stop growth throughout a series at a given time, chromacetic killing fluid was added to the drops at the end of the period of exposure and the counts and measurements were made as soon as possible. In measuring the effect of the toxic substances upon the fungi the percentage of spores germinating and the rate of growth of the sporelings were recorded. The former was determined by counting 100 spores or more per slide. The rate of growth was estimated by measuring and averaging the length of the thalli of from 10 to 40 sporelings on each slide.

FACTORS AFFECTING THE TOXICITY OF VOLATILE SUBSTANCES FROM THE EXPRESSED JUICE

METHOD OF EXTRACTION

As previously stated, no appreciable difference was found in the extracts secured by the two methods used, namely, (1) by grating the succulent bulb tissue and allowing the liquid to filter without pressure, and (2) by extracting the juice from the grated tissue through cheesecloth and then filtering.

AGE AND CONDITION OF BULBS

Yellow Globe onions of a single lot were used in nearly all these experiments. They were secured in the autumn directly after harvest and stored in a basement the temperature of which remained at 12° C. or less during the winter months but gradually approached room temperature after April 1. The investigations extended from autumn until June. During this period a reduction in the toxicity of onion extract was observed and this became especially noticeable after March. A similar reduction was noted in 1922 in onions of the previous autumn's crop obtained in the markets at Madison, Wis. It is to be expected that metabolic changes in the onion bulb continue during the protracted storage period. This apparently brings about some reduction in the volatile toxins, especially with rise in temperature. A marked difference in this respect was also noted between sprouted and unsprouted onions during the latter part of the storage period. Juice from sprouted onions has always been found to be less toxic than that of unsprouted onions from the same lot.

AGE OF CULTURES

Early experiments in which uniform results were not always secured when spores were not taken from a common source indicated that the age of the spore affected the degree of its resistance to the volatile toxins. In order to establish the importance of this factor, the spores of both *Colletotrichum circinans* and *Botrytis allii* from potato agar cultures of different ages were compared under identical conditions. The data in Table I show

that in the controls there was a reduction in viability and vitality in spores of both species as the culture aged. This reduction in vigor is correlated with a diminished resistance to the volatile toxins from the onion. This fact is especially emphasized in Figure 1, in which the average length of germ tubes of the different cultures is compared. It thus became evident that, with a given comparative series, spores as nearly uniform in vigor as possible should be used and preferably those from very young cultures.

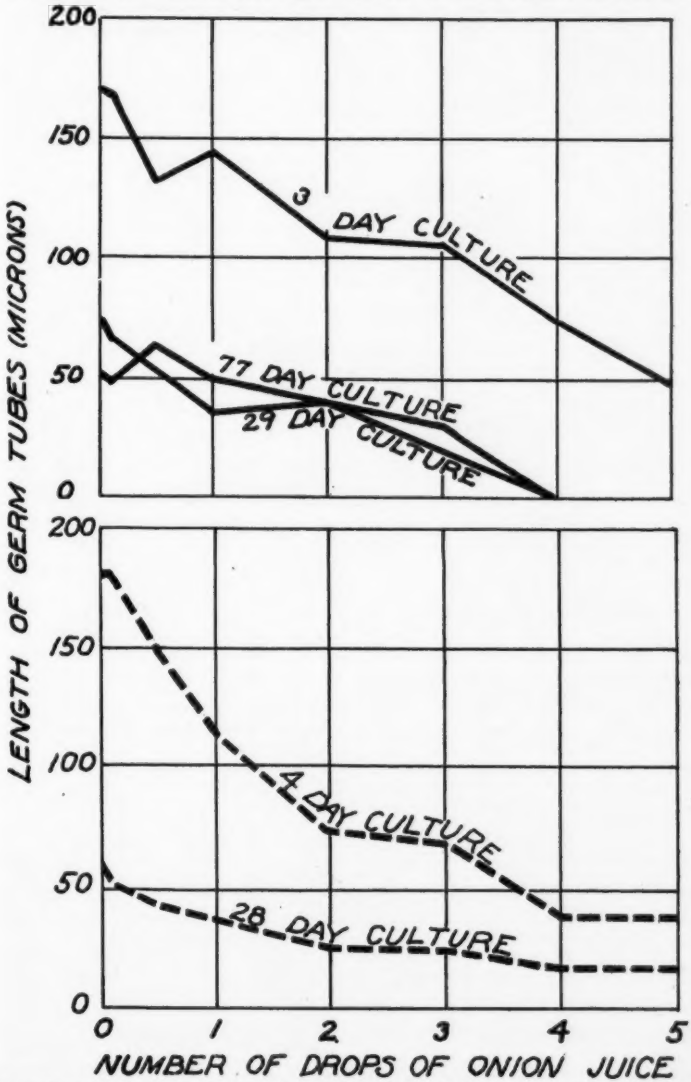

FIG. 1.—Upper graph represents the growth of sporelings of *Colletotrichum circinans* and the lower graph the growth of *Botrytis allii* from cultures of different ages, when exposed to various concentrations of volatile onion oil. See data in Table I

TABLE I.—*Comparative germination and growth rate of spores of Colletotrichum circinans and Botrytis allii of different ages in relation to the volatile substances from onion juice* [a]

Organism	Age of culture from which spores were secured		Number of drops of onion juice in chamber—									Control
			5	4	3	2	1	0.5	0.1	0.01	0.001	
	Days											
Colletotrichum circinans.	3	Germination (per cent)	93	88	93	93	91	94	95	91	93	95
		Length of germ tubes (microns).	49	73	106	108	144	132	167	165	164	170
	29	Germination (per cent)	0	0	2	7	98	98	96	99	100	99
		Length of germ tubes (microns).	0	0	.....	41	36	53	66	79	70	74
	77	Germination (per cent)	0	0	2	0	46	44	39	32	60	44
		Length of germ tubes (microns).	0	0	31	0	50	63	50	53	45	52
Botrytis allii.....	4	Germination (per cent)	78	71	98	96	86	92	91	86	84	97
		Length of germ tubes (microns).	39	39	69	74	115	149	180	171	191	180
	28	Germination (per cent)	49	67	63	78	85	88	92	85	79	85
		Length of germ tubes (microns).	18	18	25	26	37	42	53	50	57	60

[a] Duration of experiment, 13 hours at room temperature.

EFFECT OF HEATING THE EXTRACT

The effect of heat upon the toxicity of onion juice was studied. It was reported earlier by the senior author (*1*) that in onion juice which had been heated in live steam for 20 minutes the spores of *Colletotrichum circinans* germinated and the mycelium grew rapidly. Numerous repetitions of this experiment show that, although this sometimes occurs, in the majority of cases the extract will support neither germination nor growth, even though heated for an hour in the steamer or autoclaved for one-half hour. Brown (*2*) reports that the inhibitory effect of the volatile substances arising from onion juice is greatly reduced or destroyed by boiling.

It is to be expected that if the volatile onion oil consists of three compounds, as noted by Semmler (*4*), each with a different boiling point, the application of heat may remove or destroy certain of these more readily than others. Provided that they are all toxic, one would expect a gradual reduction in toxicity, depending on the temperature and the duration of heating. Two experiments on this phase of the problem are reported.

EXPERIMENT No. 1.—Juice of Yellow Globe onions was filtered and divided into four samples of 10 cc. each and a remainder which was kept for a control. Two samples each were heated for varying periods in a water bath held at 70° and two at 96° C., respectively. To one tube in each bath a reflux condenser was attached to reduce the loss of the volatile substances. One cubic centimeter samples were removed from each tube after 15, 30, 60, and 90 minutes. The samples thus obtained were tested by the usual method for the presence of volatile and dissolved toxins.

The data given in Table II and represented graphically in Figure 2 show that, on the whole, there is a gradual decrease in the amount of volatile toxin with continued heating and that the toxicity is reduced more rapidly at the higher temperatures. With the juices heated in open tubes there is a smooth curve produced, indicating a gradual loss in toxicity, but when the reflux condenser was attached there was a decided drop in both curves at 30 minutes, indicating greater toxicity in juice thus heated than in that heated only 15 minutes. Obviously, an explanation of this fact will depend upon further analysis of the volatile substances and their reaction to temperature.

The dissolved toxins were still sufficiently concentrated to kill any of the spores introduced directly into the extract.

EXPERIMENT No. 2.—Five cubic centimeters of onion juice was placed in a side-neck test tube and distilled over an open flame. About 1 c.c. of distillate was collected. The distillate and residue were then tested by the usual method for both dissolved and volatile toxins. (See Table III.) Although distillation was not continued for more than 5 minutes, the heating seems to have had

TABLE II.—*The effect of heat on the toxic volatile substances in onion juice as determined by their effect upon Colletotrichum circinans*

Source of volatile oils	Method of exposure of fungus	Treatment of juice: Method of heating	Treatment of juice: Temperature (°C.)	Response of fungus to exposure to juice heated for various intervals: Percentage of germination: 15 minutes	30 minutes	60 minutes	90 minutes	Average length of germ tubes (microns): 15 minutes	30 minutes	60 minutes	90 minutes	Response of fungus to unheated juice and to control medium: Germination (per cent)	Average length germ tube (microns)
Heated juice.	Five drops placed in moist chamber.	Reflux	70	99	99	99	98	52	39	69	81		
			96	100	99	99	99	76	68	108	91		
		Open heat	70	99	99	98	99	51	62	64	87		
			96	99	99	99	99	75	86	93	93		
	One drop of juice placed in one drop of onion decoction spore suspension.	Reflux	70	0	0	0	0	0	0	0	0		
			96	0	0	0	0	0	0	0	0		
		Open heat	70	0	0	0	0	0	0	0	0		
			96	0	0	0	0	0	0	0	0		
Unheated juice.	Five drops placed in moist chamber.	None										76	10
	One drop of juice placed in one drop of onion decoction spore suspension.	None										0	0
Control onion decoction spore suspension.		None										99	109

a decidedly destructive effect upon the volatile toxins. Both distillate and residue were practically devoid of volatile toxins, and the former contained a much reduced amount of dissolved toxin. It appears that the toxicity is due to at least two components, one of which is readily volatile and the other less so or not as all. The volatile toxins are largely broken down by boiling, while the toxic property of the residue is not destroyed by heat. This is in accord with the generally accepted view that onion oil is decomposed by distillation at ordinary pressure (*4*).

TEMPERATURE DURING THE TEST.

Certain irregularities in the results led the authors to suspect that the temperature during the experiments influenced the effect of the volatile substances upon the spores. Two sets of relations are to be considered: First, that of temperature to spore germination and growth; and, second, that of temperature to the volatilization of oil from the onion juice. The first set of conditions for *Colletotrichum circinans* has been studied previously by the senior author (*6*). It was shown that the rapidity of

TABLE III.—*The effect of distillation on the toxic substances in expressed onion juice, as determined by tests with spores of Colletotrichum circinans*

Method of exposure of fungus	Source of volatile oils	Response of fungus spores: Per cent germination	Response of fungus spores: Average length of germ tubes (microns)
5 drops placed in moist chamber	Distillate	100	94
	Residue	100	95
	Unheated juice	76	10
1 drop of liquid added to 1 drop of onion-decoction-spore suspension.	Distillate	94	18
	Residue	0	0
	Unheated juice	0	0
Control onion decoction spore suspension		99	109

germination increases up to about 20° C. and then decreases, while growth increases to about 27°, then declines abruptly. It is to be expected that the volatilization of the oil would gradually increase with the temperature up to a much higher degree. A marked difference in the rate of depletion of volatile toxins in expressed onion juice held at high and low temperatures is shown in Table IV. Juice from a common source was divided into two lots immediately after extraction; one lot was placed in the ice box, the other in a constant temperature incubator at 25°. Tests with juice from the two lots at given intervals show that at the higher temperature the volatile toxins disappear within a very few hours and before any evidence of bacterial fermentation was noted. In the juice kept at the lower temperature the volatile toxins were still distinctly evident after 22 hours. The dissolved toxins persisted apparently until fermentation by contaminating organisms had reached an advanced state.

In view of this evidence that the rates of volatilization of the oil varies greatly from 10° to 25° C., it is to be expected that the temperature at which spore germination tests are made may influence the results. The extent of this influence was not as great as might be expected. Several experiments were conducted in which various amounts of onion juice were placed in constant temperature incubators over a range of 10° to 28°. Evidently the lowering of temperature had sufficiently similar retarding effects upon volatilization of the oils and upon

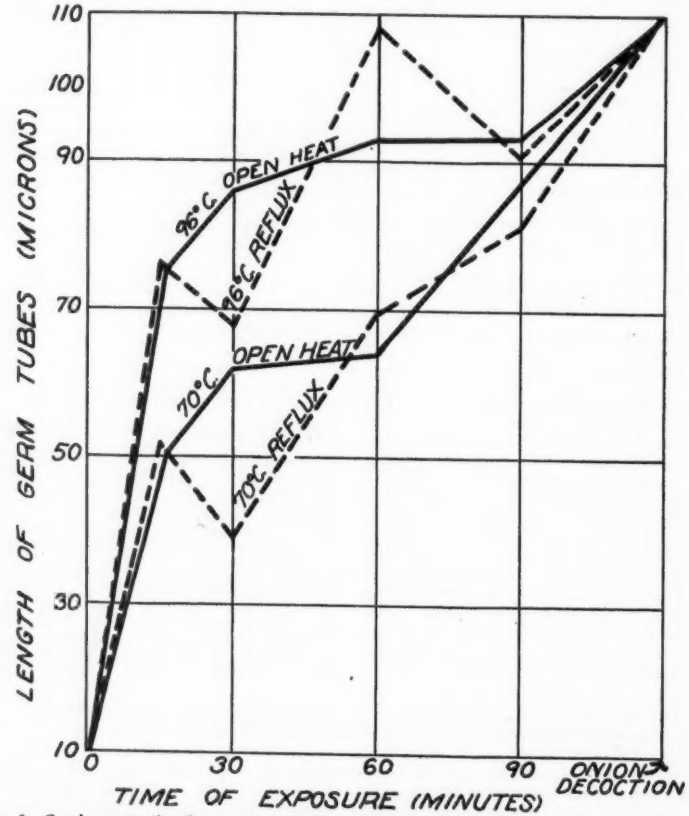

FIG. 2.—Graph representing the growth of sporelings of *Colletotrichum circinans* when exposed to two lots of onion juice which have been heated at 70° and 96° C., respectively, for various intervals either in an open vessel or in a vessel to which a reflux condenser had been attached. (See data in Table III)

germination of spores of *Colletotrichum circinans* so that no perceptible difference in the toxic action at various temperatures resulted. As a further safeguard, however, practically all of the experiments were run at a constant temperature of 25°.

result, under extremely moist conditions, and the cell lumen may be invaded before the cell collapses. Under ordinary storage conditions, however, the progress is very slow and at least in a majority of cases hyphae do not penetrate the living cells, but the latter

TABLE IV.—*Relation of temperature to the rate of depletion of the toxins in onion juice* [a]

Number of hours after extraction	Reaction of spores of *Colletotrichum circinans*									
	Juice kept in ice box					Juice kept at 25° C.				
	Reaction to volatile toxins				Spores placed directly in juice	Reaction to volatile toxins				Spores placed directly in juice
	2 drops	1 drop	0.1 drop	0.01 drop		2 drops	1 drop	0.1 drop	0.01 drop	
0	0	0	0	+	0	0	0	0	+	0
2					0	0	0	+	+	0
4					0	−	+	+	+	0
8					0	+	+	+	+	0
15	0	0	+	+	0	+	+	+	+	0
22	0	0	+	+	0	+	+	+	+	0
46	⊖	+	+	+	0	+	+	+	+	0
90					0					0

[a] Symbols used: 0=no germination; ⊖=slight germination and retarded growth; −=medium germination and growth; +=good germination and growth.

ORGANISMS USED AND THEIR MODE OF ATTACK

For the extension of this study certain of the more common onion bulb parasites were considered. These, with the smudge fungus, were representatives of the four genera, Colletotrichum, Fusarium, Botrytis, and Aspergillus. To further supplement the comparative study one or more species from each of the first three genera and one from Glomerella, all of which were nonpathogenic to the onion, were added. As introductory to a consideration of further experimental data, the existing knowledge of the mode of attack of each of the onion parasites will be reviewed.

COLLETOTRICHUM

The onion smudge organism (*Colletotrichum circinans*) and its method of infection have already been described (*6*). Of importance in this connection is the fact that penetration always occurs directly through the cuticle by means of an infection hypha which is produced from an appressorium. Softening and invasion of the cell wall show signs of degeneration and collapse before invasion actually occurs. It appears, therefore, that this fungus, even after infection, seldom actually invades the living cells. These studies were made with northern Globe varieties. More recent observations of the White Bermuda variety indicate that it may be parasitized more readily by *C. circinans* than the northern varieties, but this is a matter still under investigation.

Other species of Colletotrichum and Glomerella were picked at random for comparison with *C. circinans*, none of them being parasitic upon onion.

BOTRYTIS

The onion neck-rot fungus (*Botrytis allii*) has been described by Munn (*3*). It is a wound parasite and ordinarily infects through injuries in the neck of the bulb. Munn has shown that this fungus secretes an enzyme which kills the bulb tissue in advance of the mycelium. Here also we have the organism living out of immediate contact with the living host cell.

A second species (*Botrytis sp.* 108a) [1] commonly occurs on the outer scales of white onion, causing what is known as

[1] For the purposes of this paper this form will be referred to as *Botrytis sp. 108a*. A full description of the species will shortly be published.

small sclerotial neck rot. As with *B. allii*, it usually enters through wounds at the neck but attacks the succulent scale tissues less rapidly than does *B. allii*.

Two strains of *Botrytis cinerea* Pers. were also included. One strain was isolated by the writers from cyclamen, the other was secured from G. B. Ramsey, who had isolated it from tomato. The parasitic behavior of this species has been described most recently by Brown (*1*). Its method of invasion on other plants is very similar to that described by Munn (*3*) for *B. allii*, except that *B. cinerea* may penetrate the leaf cuticle. Inoculation experiments with these strains on onion bulbs yielded only negative results.

FUSARIUM

Two strains of Fusarium (*Fusarium cepae* Han. and *Fusarium* sp. 45) isolated from onion and determined by inoculation to be capable of causing the common Fusarium bulb rot were used. For comparison, the wheat-scab organism, *Fusarium graminearum* Schwabe (*Gibberella saubinetii* (Mont.) Sacc.) was included. The onion Fusaria are parenchyma invaders. They enter principally through wounds at the base of the bulb and cause a semiwatery decay (*8*). The exact relation of parasite to host tissue has not been studied.

ASPERGILLUS

Two forms of Aspergillus were used. The black mold fungus (*Aspergillus niger* Van Tiegh.) is a common storage fungus, especially upon the southern Bermuda crop (*5*). The organism develops on the dead outer scales or between the succulent scales of the bulb, and the invasion of sound healthy scales is comparatively meager. Upon injection into wounds on the bulb it does not cause decay. It appears to have no marked preference between colored and white varieties of the Bermuda types.

A second species of Aspergillus, isolated from Italian garlic by E. D. Eddy, was used for comparison. This produces yellow spores and dark-brown sclerotia in abundance. Charles Thom of the Bureau of Chemistry, United States Department of Agriculture, to whom the culture was referred, is at present working upon the classification of this and related forms, and for the purposes of this discussion it will be referred to by his number, 4660. When spores and mycelium were injected into wounds in onion bulbs, a rapid decay resulted. In contrast to *A. niger*, then, it appears to be an active parasite of the onion bulb.

GERMINATION AND GROWTH IN ONION JUICE

It has already been shown (*7*) that ordinarily spores and mycelium of *C. circinans* neither grow nor survive in the undiluted juice expressed from onion scales. This is probably due for the most part to the residual, nonvolatile toxin which remains in the extracted cell sap. It is obvious therefore that the fungus hyphae would not invade the lumen of the host cell without some change in the contents of the latter being produced in advance of them or at least not without being protected by the plasma membrane of the host. It appears that changes in the host cell do occur in advance of the onion smudge organism (*6*). It was of interest to determine whether the extracted juice was similarly toxic to other bulb parasites. Spores of each of the fungi mentioned were placed in drops of expressed onion juice which was diluted to various degrees with distilled water. The results are recorded in Table V.

It was found that, with one exception, none of the spores germinated in undiluted juice. Very little germination occurred in a dilution of 1 to 1. It was generally true of all these fungi that germination and growth increased with greater dilution. This points to the presence of toxins, rather than lack of nutrient as the principal inhibitory factor, inasmuch as dilution decreases the amount of available food. In the dilution of 1 to 10 it is noteworthy that all three species of Colletotrichum were still completely inhibited, while the species of Botrytis and Fusarium which are pathogenic to onions germinated and grew. In these two genera the nonpathogenic species tried were still almost completely inhibited. It is interesting also to compare the two species of Aspergillus. *A. sp. 4660*, which is a vigorous bulb-decaying organism, grows well in the 1 to 10 dilution, while *A. niger*, a superficial fungus, is entirely inhibited. The differences in the behavior of the various species becomes less marked in the higher dilutions.

It is significant that of the onion parasites, the organisms causing the most rapid decay (*Botrytis allii*, *Fusarium cepae*, *Fusarium* sp. 45, and *Aspergillus* sp. 4660) show germination and growth in the 1 to 10 or in lower dilutions, while the least aggressive parasites (*Colletotrichum circinans* and

TABLE V.—*The effect of concentration of expressed onion juice upon germination and growth of various fungi*

Organism	Expressed onion juice					Onion decoction
	Undiluted	Diluted 1 to 1	Diluted 1 to 10	Diluted 1 to 100	Diluted 1 to 1,000	
Colletotrichum circinans:						
Percentage germination	0	0	0	91	89	84
Average length germ tube (microns)	0	0	0	123	164	165
Colletotrichum lindemuthianum:						
Percentage germination	0	0	0	0	1	57
Average length germ tube (microns)	0	0	0	0	----	25
Colletotrichum pisi:						
Percentage germination	0	0	0	60	88	100
Average length germ tube (microns)	0	0	0	11	15	
Glomerella cingulata:						
Percentage germination	0	28	50	26	56	75
Average length germ tube (microns)	0	1	1	1	2	37
Botrytis allii:						
Percentage germination	5	99	100	100	100	100
Average length germ tube (microns)	62	85	200	200+	500+	500+
Botrytis 108a:						
Percentage germination	0	99	100	100	100	100
Average length germ tube (microns)	0	300+	500+	500+	500+	500+
Botrytis cinerea:						
Percentage germination	0	0	80	100	100	100
Average length germ tube (microns)	0	0	9	244	500+	500+
Fusarium No. 45 (onion):						
Percentage germination	0	6	14	62	89	88
Average length germ tube (microns)	0	10	8	14	29	22
Fusarium cepae:						
Percentage germination	0	0	1	90	98	94
Average length germ tube (microns)	0	0	22	54	89	34
Fusarium graminearum:						
Percentage germination	0	0	1	95	96	100
Average length germ tube (microns)	0	0	12	33	75	137
Aspergillus 4860:						
Percentage germination	0	0	93	----	----	100
Average lenght germ tube (microns)	0	0	26	----	----	87
Aspergillus niger:						
Percentage germination	0	0	0	62	43	85
Average length germ tube (microns)	0	0	0	24	33	145

Aspergillus niger) show little or no germination and growth below the 1 to 100 dilution. In correlation with this fact it is found that the last two fungi neither occur as natural wound parasites nor do they cause infection when artificially inoculated into wounds. The other four organisms are normally wound parasites. As already noted by Walker and Tims (*8*), inoculation of onion bulbs with *Fusarium cepae* by injecting spores into fresh needle wounds usually yields negative results, unless the bulbs are kept in moist chambers for about 48 hours after inoculation. The exact nature of this phenomenon needs further study. It is probable that the cell sap exuding into a fresh wound has a great deal to do with the inhibition of this organism, which becomes a vigorous parasite when once established in the host tissue. Similarly the writers have noted in inoculation experiments with *Botrytis allii* that when onion bulbs, the necks of which have been clipped so as to expose freshly exuding cell sap, are sprayed with a spore suspension, sometimes an unusually small percentage of bulbs becomes diseased. When these organisms become established as in nature, either in somewhat more dilute cell sap or in meteoric water on the surface of the dead tissue at the neck of the bulb, it is evident that they overcome the toxic effects sufficiently to make progress.

EFFECT OF VOLATILE SUBSTANCES UPON GERMINATION AND GROWTH

Preliminary experiments on the effect of volatile onion oil upon germination and growth showed that all species were somewhat retarded. Following the methods already outlined and providing as uniform conditions as possible, the fungi were compared by using spores from fresh cultures, and exposing them to various amounts of toxin from a common source at a temperature of 25° C. Although many repetitions of this experiment were made, one representative set of data is presented for consideration. The results on spore germination are given in Table VI and those on growth of the sporelings in Table VII.

In comparing first the reaction of the several onion parasites (fig. 3), it is to be noted that there is again a rough negative correlation between aggressiveness of parasitism and sensitiveness to the volatile toxins. As evidenced both in germination and growth, *Colletotrichum circinans* is the most sensitive; *Aspergillus niger* is next; both of these are very weak parasites.

The reactions of the nonparasitic species do not lend themselves to any very general statement. Lack of pathogenic properties upon the onion is not necessarily correlated with high sensitiveness to volatile oils. In this case at least *Botrytis cinerea* was stimulated in germination and growth by exposure to the volatile oil. *Fusarium graminearum*, *Colletotrichum lindemuthia-*

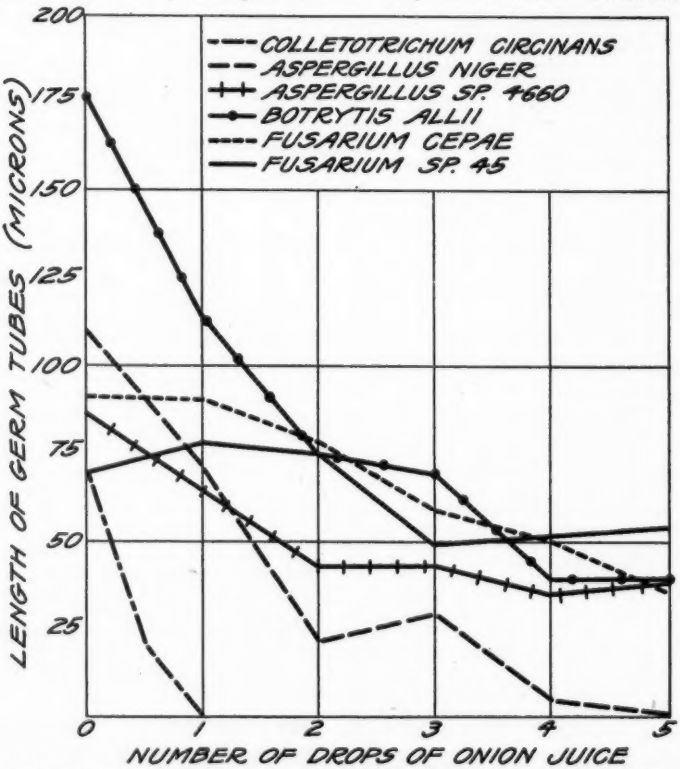

FIG. 3.—Graph representing the growth of sporelings of several onion-bulb parasites, when exposed to various concentrations of volatile onion oil. See data in Table VII. Note that the two weakest parasites, *Colletotrichum circinans* and *Aspergillus niger* are the most retarded by the volatile toxins as compared with the other four forms which are aggressive parasites of the onion bulb

In contrast to this, the more aggressive bulb-rotters (*Botrytis allii*, *Fusarium cepae*, *Fusarium* sp. 45, and *Aspergillus* sp. 4660) all show more or less germination and growth in the highest concentration of toxin. The trend therefore coincides in a general way with that noted for dissolved toxins (Table VI). Botrytis 108a occupies an intermediate position between the two groups, being a rather weak parasite, but still exhibiting considerable resistance to the volatile toxins.

num, and *C. trifolii* were distinctly inhibited, while *C. pisi* and *Glomerella cingulata* were only slightly retarded.

DISCUSSION OF RESULTS

In the establishment of the parasitic relation the factor most important to the invader is the presence of food, and one of the principal opposing factors is the presence of toxic substances within the host tissues. Since different species of fungi vary in their response to these antithetic factors, the question

TABLE VI.—*The effect of the volatile components of onion extract on the spore germination of several fungi*

Organism	Percentage of germination									
	Number of drops of onion juice in chamber									Control
	5	4	3	2	1	0.5	0.1	0.01	0.001	
Colletotrichum circinans	0	0	0	0	0	65	68	41	74	86
Colletotrichum lindemuthianum	0	0	0	0	0	0	77	60	64	57
Colletotrichum trifolii	0	0	0	0	40	17	30	27	------	38
Colletotrichum pisi	0	90	89	97	100	100	100	100	100	100
Glomerella cingulata	0	0	87	87	76	75	72	73	61	74
Botrytis allii	78	71	98	96	86	92	91	86	84	97
Botrytis 108a	90	------	90	95	100	100	100	100	100	100
Botrytis cinerea	71	78	83	63	37	23	9	29	24	30
Fusarium cepae	95	95	------	98	93	92	96	93	94	98
Fusarium No. 45 (onion)	30	------	64	86	70	------	94	94	96	89
Fusarium graminearum	0	0	0	0	100	95	90	97	96	98
Aspergillus niger	0	0	80	68	90	95	93	94	83	93
Aspergillus 4660	48	99	99	100	100	100	100	100	------	100

is pertinent to the relative importance of the latter in determining the degree of parasitism. There are several parasites of the onion bulb which vary in the mode and the aggressiveness of their attack. *Colletotrichum circinans* penetrates the cuticle readily at any point but once having gained entrance progresses very slowly, although it is not devoid of cellulose-digesting properties. *Botrytis allii* does not readily enter the unbroken surface but almost always enters through wounds or through dead neck tissues. Once within the host it readily kills the tissue slightly in advance of the hyphae and it is a much more aggressive parasite than *Colletotrichum circinans*. *Fusarium cepae* and *Fusarium* sp. 45 also gain entrance principally through wounds but cause very rapid decay having once entered. Two species of Aspergillus offer a similar contrast. One (*A. niger*) is very superficial and only mildly parasitic, while the other (*Aspergillus* sp. 4660) decays the tissue very rapidly.

These differences may originate in food relations, enzyme production by the invader, or antagonistic substances within the host. The present study is limited to the last question and has sought to determine what differential reactions on the part of bulb-rotting fungi and their allies occur in relation to toxic substances in onion tissue.

Inquiry into the nature of the inhibitory substances in the fleshy scales of the onion bulb shows that they are of at least two kinds. One type present in extracted juice is not readily removed or broken down by boiling and

TABLE VII.—*The effect of the volatile components of onion extract on the growth of sporelings of several fungi*

Organism	Length of germ tubes (microns)									
	Number of drops of onion juice in chamber									Control
	5	4	3	2	1	0.5	0.1	0.01	0.001	
Colletotrichum circinans	0	0	0	0	0	22	28	25	43	72
Colletotrichum lindemuthianum	0	0	0	0	0	0	12	21	29	25
Colletotrichum trifolii	0	0	0	0	6	9	13	14	0	12
Colletotrichum pisi	0	10	11	14	51	66	84	85	83	88
Glomerella cingulata	0	0	4	8	11	25	27	36	31	32
Botrytis allii	39	39	69	74	115	149	180	171	191	180
Botrytis 108a	151	------	107	215	184	228	197	176	223	185
Botrytis cinerea	14	22	21	35	57	50	58	80	62	60
Fusarium cepae	18	25	------	30	45	48	48	45	40	46
Fusarium 45 (onion)	18	------	16	25	26	------	24	22	25	23
Fusarium graminearum	0	0	0	0	44	90	132	166	170	170
Aspergillus niger	0	5	29	22	71	73	85	135	112	111
Aspergillus 4660	38	35	43	43	64	64	80	80	0	87

remains active apparently until the juice is destroyed by bacterial fermentation. The other type is volatile, and at ordinary room temperatures largely disappears from extracted juice within a few hours. It is destroyed by distillation at ordinary pressure. A third type of substance toxic to fungi is found in the dry outer scales of colored onion bulbs, and studies on it are published in other papers (*6*, *9*). While some of this third type may exist in the extract of fleshy colored scales it is probably too dilute there to be effective, and is considered distinct from the two types discussed here. These last two types appear to exist to about the same extent in white and colored onion bulbs.

By testing the reaction of these fungi of the two types of toxic substances under as nearly uniform conditions as possible some interesting results have been noted. The response to the two kinds of toxin is in general very similar for each fungus. Comparing onion pathogens and nonpathogens no strict negative correlation was found between pathogenicity upon onion and sensitiveness to the toxins. This simply indicates that other factors enter into the determination of the parasitic relation.

But to compare the onion pathogens as among themselves, it must be remembered that this method of exposure to the toxins is only an approximation to natural conditions. Whereas in our tests the fungus was exposed directly to the dissolved and volatile toxins, it is probable that in nature this exposure is not so severe nor direct. In the case of each of the bulb parasites considered here the host cells are affected somewhat in advance by the fungus enzymes and in this interaction the inhibitory effects of these host toxins are probably weakened. But in any case, it is plausible to suggest that these toxins may retard the advance of the parasite according to the specific sensitiveness of the latter. In support of this is the fact that *Colletotrichum circinans*, although it is able to penetrate the onion scales readily, is the most sensitive to the host toxins and is among the least aggressive as a parasite. *Aspergillus niger*, though slightly less sensitive to the toxins, is also decidedly limited in its properties as a decay-producing organism. *Botrytis allii*, once established, is one of the most aggressive of the bulb parasites, and in addition to its advantage of possessing more active cytoltic properties, it is also much less sensitive to the host toxins.

Botrytis sp. 108a is slightly less sensitive than *Botrytis allii*, although we should expect it to be somewhat more so should this factor be the only one which determines its weaker aggressiveness. In this case, and indeed in all the forms considered, further study should be directed toward a consideration of the enzym activities and food requirements of the organisms. The other active bulb invaders, *Fusarium cepae*, *Fusarium sp.* 45, and *Aspergillus sp.* 4660, fall into the general class with *Botrytis allii* as to their sensitiveness to the toxins and this is in correlation with their parasitic activity. It would appear from the evidence at hand that the toxic constituents of the host cell sap of the onion may exert an important influence on the aggressiveness of the fungi pathogenic to that plant. Any broader generalization at this time would not be justified.

SUMMARY

1. This investigation is a continuation of one previously reported in which was demonstrated the toxic nature of juice extracted from fleshy onion bulb scales toward the onion smudge organism (*Colletotrichum circinans*).

2. These toxins are of two general types, one which is neither removed nor broken down readily by heat and one which is volatile and passes off from the extracted juice at room temperature within a few hours.

3. There is a gradual decline during storage of onion bulbs in the amount of volatile toxin which may be released from the extracted juice. This decline is also evident on sprouting.

4. In general fungus spores become more sensitive with age to the volatile toxins.

5. The temperature at which spores are tested may have some influence on their reaction to the volatile toxins and it thus becomes essential to provide as uniform conditions as possible for comparative studies. The depletion of volatile toxins in onion juice is hastened by increase in temperature.

6. The primary purpose of the investigation was to compare representative onion bulb parasites with one another and with other fungi nonpathogenic to onion in their reaction to these toxins. The following bulb parasites were included: *Colletotrichum circinans*, *Boytrytis allii*, *Botrytis* sp. 108a, *Fusarium cepae*, *Fusarium* sp. 45, *Aspergillus niger*, *Aspergillus* sp. 4660. Nonparasitic forms were: *Colletotrichum lindemuthianum*, *C. trifolii*, *C. pisi*, *Glomerella cingulata*, *Botrytis cinerea*, and *Fusarium graminearum* (*Gibberella saubinetii*).

7. In general, the reaction of each fungus followed the same trend for the dissolved as for the volatile toxins.

8. Comparing onion pathogens and nonpathogens, there is no strict negative correlation between pathogenicity upon onion and sensitiveness to the toxins, which only indicates that other factors enter into the determination of the parasitic relation.

9. Considering the onion parasites as between themselves there is evident a negative correlation between aggressiveness of parasitic attack and sensitiveness to the dissolved and volatile toxins. It is pointed out that the experimental results are not truly representative of the actual relation between host and parasite. The presumption, however, is that as the parasite invades the tissue the host toxins, though attenuated by fungous enzymes, may possibly exert some retarding effects upon the invader. If this be the case, it is suggested that the host toxins may be one of the numerous factors which determine the degree of parasitism attained by a given parasite.

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BORAX AS A DISINFECTANT FOR CITRUS FRUIT[1]

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The use of disinfectants in washing citrus fruits has been a common practice in California for many years. In 1906 Smith[2] showed that the brown-rot of lemons caused by *Pythiacystis citrophthora* Smith and Smith, could be controlled by a solution of potassium permanganate, copper sulphate, or formalin in the wash water. Since then copper sulphate has been used to a considerable extent commercially. For fifteen or twenty years hot water and soap have been employed in washing both oranges and lemons, and for the past ten years a soap containing borax has been extensively used. It has also been a common practice in some packing houses to use a dilute solution of borax in the wash water in addition to the soap. Except in the case of brown-rot of lemons, there appears to be no data on the exact effect of these various disinfectants in the control of the fungous diseases of Citrus which gain entrance to the fruit in handling and harvesting operations and are particularly evident during transit and on the market.[3] To obtain more exact information upon the possibilities of controlling some of the common Citrus parasites such as blue mold, caused by *Penicillium italicum* Wehmer, and green mold, caused by *Penicillium digitatum* Sacc., a series of experiments was conducted in which some common and cheap disinfectants were used in the wash water. Since the results of these investigations were fairly definite and present a basis for further commercial application of disinfectants in the control of certain Citrus diseases, a preliminary presentation is here given.

The work was begun in California early in 1924, either Navel or Valencia oranges being used in all experiments described in this paper. In the first preliminary experiment, powdered boric acid U. S. P. and potassium alum Tech. were used. Navel oranges, which had been picked from four to six weeks, were prepared for the experiment by removing thin slices of skin from each fruit. Seventy-five fruits were immersed for five minutes in a solution of 2.5 per cent of boric acid at a temperature of 120° F.; two other lots of 75 each were treated, one by immersing in a solution of 4.5 per cent powdered alum and the other in hot water only for five minutes at 120° F. After the fruits had been removed from the baths they were inoculated with spores of blue mold obtained from a decayed fruit. The fruit was dried, packed, and stored in a room having a temperature of about 70° F. and a humidity of about 90 per cent. After one week both the fruit treated with hot water and that treated with powdered alum solution showed 100 per cent decay caused by blue mold. The lot treated with boric acid showed only 2.5 per cent decay from blue mold and about the same percentage from green mold. Further holding of the lot showed some decay from what seemed to be *Alternaria* sp. or *Pythiacystis* sp. In this connection it is interesting to note that Smith[4] found that very dilute solutions of boric acid would not control *Pythiacystis citrophtora* on lemons.

This experiment indicated that boric acid offered very promising possibilities and that alum was apparently of no particular value in concentrations such as could safely be used in washing the fruit. Borax (technical grade) was later tested and found to be as effective as boric acid in controlling blue-mold decay, and, being much cheaper, was used in all later experiments. The investigation here described was concerned mainly with testing the efficiency of a 2.5 per cent solution of borax at various temperatures and with different methods of application in the control of blue and green mold which had been inoculated

[1] Received for publication Aug. 31, 1924; issued April, 1925.

[2] SMITH, R. E., and others. THE BROWN-ROT OF THE LEMON. Calif. Agr. Exp. Sta. Bul. 190, 72 p., illus. 1907.

[3] POWELL, G. H., and others. THE DECAY OF ORANGES WHILE IN TRANSIT FROM CALIFORNIA. U. S. Dept. Agr., Bur. Plant Indus. Bul. 123, 79 p., illus. 1908.

[4] SMITH, R. E. OP. CIT.

on the surface of wounded fruit and in punctures similar to those made by stem or thorns.

The fruit was prepared for inoculation either by cutting thin slices of the rind just below the oil cells and into the white portion similar to the wound made by a clipper cut or by puncturing the rind with a knife to the depth of about 2 mm. The depth the knife was thrust into the fruit was controlled by wrapping tire tape around the blade so that it could penetrate the fruit only to the depth required. The inoculations were made by rubbing spores on the cut surface, where a portion of the rind was sliced away, and by dipping the knife in a mass of spores when making the wound by puncture. The spores for inoculating the fruit were obtained from decayed oranges. Since the greater part of this work was done under ordinary packing-house conditions and with the regular packing-house machinery, no attempt was made to get pure cultures of the fungi for making inoculations. Decayed oranges were selected, however, as the source of spores, because judging from the external character and color (*1*, *3*), these seemed to furnish practically pure cultures of the fungi.[5] In many cases, undoubtedly, the fruit was inoculated from mixed cultures and there was especially in the controls considerable possibility of natural inoculations when the regular packing-house machinery was used in handling the fruit.

In the early experiments the procedure was to wound the fruit, treat it with a 2.5 per cent solution of borax, either by immersing or floating it in this solution, inoculating it by rubbing a finger dipped in the blue mold spores on the cut surface, drying in the air, wrapping, packing, and storing. The fruit was usually stored at about 70° F. with a humidity of about 90 per cent. Controls were prepared in exactly the same way except that instead of being treated with the borax solution they were treated with water only and inoculated with the fungi. At the end of one week the fruit was examined, the decayed fruits classified and removed, and the remaining sound fruits allowed to remain for the next inspection. When the fruit was immersed, it was held about 4 inches below the surface of the solution by a rack. When it was floated no weight was used, and it was allowed to float freely in the tank of solution, from one-eighth to one-tenth of the rind being exposed above the surface. The results of the experiments made with blue mold fungus on Valencia oranges are shown in Table I.

Table I shows that there is much more decay in the untreated fruit after one week than in any of the borax-treated lots. In the latter the best results were obtained at the higher temperatures and when the fruit was allowed to remain for four minutes or more in the solution. In no case was there more than 4.5 per cent of blue mold in any of the lots treated at 120° F. except in the two lots sprayed with water after being treated with the borax solution. In these lots the decay caused by blue mold after one week was 6.1 and 7.8 per cent. Evidently for the best results the borax solution should be allowed to dry on the fruit. At the higher temperatures blue mold is apparently controlled as well by allowing the fruit to float in the borax solution as by immersing it. At the lower temperatures, however, floating did not give as good results as did immersion. In the lots of fruit injured by puncturing and inoculating in these wounds, practically as good control was obtained as when the wounds were superficial.

The results of the inspections after two weeks show some increase in the amount of blue mold present in the treated fruit, although in the lots treated at 120° for eight minutes there was in no case more than 5 per cent of blue mold decay. There was little increase in blue mold decay after five to seven weeks. The amount of decay caused by green mold was very much higher during the later inspections than at the first. This fungus is apparently not so easily controlled by borax as is the blue mold fungus. Results of a series of experiments on the treatment of Valencia oranges inoculated with green mold are shown in Table II. The spores for inoculating this fruit were obtained from decayed specimens which appeared to be affected only with green mold, although, of course, as in the case of blue mold there was probably some contamination.

An inspection of Table II corroborates the observation indicated by Table I, namely, that green mold is not readily controlled by treatment with this concentration of borax. In the lots of fruit wounded on the surface and immersed, there was no apparent infec-

[5] THOM, C. CULTURAL STUDIES OF SPECIES OF PENICILLIUM. U. S. Dept. Agr., Bur. Anim. Indus Bul. 118, 109 p., illus. 1910.

TABLE I.—*Showing percentage of decay in Valencia oranges, wounded on surface or punctured, immersed or floated in a 2.5 per cent solution of borax, inoculated on the wounds with blue-mold spores, and held in a warm room at high humidity*

Treatment	Temperature bath	Time	Number of fruit	Percentage of decay after—							
				One week		Two weeks		Five weeks		Seven weeks	
				Blue mold	Green mold	Blue mold	Green mold	Blue mold	Green mold	Blue mold	Green mold
	°F.	*Minutes*									
Control wounded and inoculated but not treated with borax			73	98.6	0						
			100	100.0							
			513	90.0							
			686			92.4	0				
			100	100.0							
Wounded on surface, immersed in borax solution and inoculated	73	4	100	13.0	17.0	14.0	66.0	14.0	84.0		
	73	8	13	0	0	0	15.3				
	120	3	224	4.4	2.6						
	120	3	459			9.3	32.4				
	120	3	224	4.5	0						
	120	4	75	2.6	2.6						
	120	4	15	0	6.6						
	120	4	395	2.2	1.2						
	120	4	972			12.7	36.0				
	120	4	485	2.3	0						
Wounded on surface, floated in borax solution and inoculated	73	4	100	41.0	16.0	42.0	48.0	42.0	54.0		
	120	8	423	0	0						
	120	8	488			4.9	25.8				
Wounded on surface, immersed in borax solution, inoculated, and rinsed with water	73	4	50	26.0	16.0	26.0	38.0	26.0	60.0		
	73	6	50	60.0	8.0	64.0	24.0	64.0	36.0		
Wounded on surface, immersed in borax solution, inoculated and sprayed with water	120	6	587	6.1	6.8						
	120	6	701	7.8		45.1	30.1				
Control punctured and inoculated; not treated with borax			250	83.6	0	84.8	0	86.0	0		
Wounded by puncturing, inoculated and immersed in borax solution	70	8	50	0	0	2.0	0	2.0	4.0	2.0	4.0
	120	4	100	2.0	0	6.0	4.0	6.0	46.0	7.0	53.0
	120	6	100	0	0	2.0	3.0	2.0	34.0	3.0	40.0
	120	8	150	3.3	0.6	4.6	2.6	5.3	30.0	5.3	37.9

TABLE II.—*Showing percentage of decay in Valencia oranges, wounded on surface or punctured: immersed or floated in a 2.5 per cent solution of borax, inoculated with green mold spores, and held in a warm room at high humidity*

Treatment	Temperature bath	Time	Number of fruit	Percentage of decay after—							
				One week		Two weeks		Five weeks		Seven weeks	
				Blue mold	Green mold	Blue mold	Green mold	Blue mold	Green mold	Blue mold	Green mold
Control wounded on surface and inoculated, not treated with borax	°F.	*Minutes*	100	80.0	20.0						
Wounded on surface and immersed in borax solution	67	4	100	0	27.0	0	97.0	0	99.0		
	67	8	100	0	15.0	0	92.0	0	95.0		
	120	4	100	0	24.0	0	92.0	0	98.0		
	120	8	100	0	2.0	0	50.0	0	73.0	0	80.0
Control wounded by puncturing, inoculated, not treated with borax			37	0	100.0						
Wounded by puncturing, inoculated and immersed in borax solution	73	4	100	11.0	2.0	15.0	2.0	18.0	24.0	19.0	28.0
	73	6	100	16.0	0	18.0	7.0	21.0	45.0	22.0	50.0
	70	8	46	0	8.7	0	48.0	0	84.8		
Same except treated by floating in borax solution	73	4	50	8.0	0	8.0	4.0	10.0	42.0	10.0	44.0
	73	6	50	14.0	0	18.0	4.0	18.0	26.0	18.0	32.0

tion from blue mold but at the end of five weeks 73 per cent or more of the fruit had decayed from what apparently was green mold. With the fruit inoculated by puncturing and immersion, the results are not so striking; there is considerably more blue mold present, indicating contamination of the culture used for inoculation. The percentage of rot caused by green mold as shown by the later inspections is high in all cases, although it was above 50 per cent in only one case.

From the results of the experiments herein reported it is evident that blue mold rot, which causes so much damage to Citrus fruit in California, can be largely controlled by treating the fruit with a solution of borax. Much of the work described in this paper was done in the packing house and with equipment suitable for application in a commercial way. It remains, however, to make further experiments on a commercial basis, to determine the value of the treatment in actual shipping and marketing tests. While borax [6] in the concentration used is not so effective in the control of green mold as in that of blue mold, it is probable that higher concentrations of borax or other disinfectants may be found which will be effectious against this fungus. Work along these lines is in progress.

[6] The question as to whether treatment with borax should be indicated by special label or otherwise for nterstate shipment has not yet been determined.

THE OCCURRENCE OF COPPER, MANGANESE, ZINC, NICKEL, AND COBALT IN SOILS, PLANTS, AND ANIMALS, AND THEIR POSSIBLE FUNCTION AS VITAL FACTORS[1]

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INTRODUCTION

A problem of fundamental importance in agricultural research to-day is to ascertain which of the elements present in small quantities in soils, plants, and animals are necessary in the vital processes and what are their functions. The purpose of this paper is to show that some of the so-called nonessential elements are of common occurrence in Kentucky soils and in certain tissues of plants and animals produced on such soils and that their concentration is greatest in certain vital organs of plants and animals, a coincidence which suggests the possibility that such elements may have important functions in the life processes.

HISTORICAL DATA

For a long time it has been taught and accepted that available compounds of only 10 elements are all that are necessary for the normal growth and maturation of agricultural crops. It is a well-known fact, however, that a much larger number of elements than 10 occur in small amounts in fertile soils and in the ashes of normal plants that have grown in the soil. Palladin (*13*, p. 82)[2] names 31 elements that have been found in the ashes of plants grown under natural conditions in the soil. The 10 elements which have heretofore been considered sufficient for the growth of plants are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, and iron.

Within the past 50 years many investigations have been recorded in chemical literature which show that the elements arsenic, antimony, cadmium, copper, manganese, zinc, nickel, cobalt, barium, strontium, bromine, and iodine are widely distributed in soils and plants. In recent experiments observations have been made which indicate that a few of the so-called nonessential elements may have more important functions in soils, plants, and animals than is generally recognized.

Greaves (*3*, p. 119) states that arsenic is a constituent of virgin soils and that certain compounds of this element stimulate the processes of ammonification, nitrification, and nitrogen fixation in the soil.

In 1866 Neubauer (*12*) published a method for the estimation of copper in the tissues of plants and animals. Later investigations show that this element is widely distributed in natural waters, soils, plants, and animals. Certain species of mollusks are known to be relatively rich in copper.

Willard (*16*) reports that in 34 different samples of oysters collected at different points along the East Coast of the United States a minimum of 50 parts per million and a maximum of 1,700 parts per million of copper was found in the moisture-free matter.

Bertrand (*2*) has published results which show quite appreciable amounts of arsenic, boron, iodine, copper, manganese, zinc, and fluorine to be of common occurrence in the tissues of plants and animals. He also offers the suggestion that copper, manganese, and vanadium may replace the function of iron in certain mollusks, crustacea, and tunicates.

Benzon (*1*) has recently published data from which he concludes that zinc functions as the so-called water-soluble vitamin B.

Javillier (*5*, *6*, *7*) has shown that zinc is a constituent of normal plants and that conifers are relatively rich in this element. He concludes that plants which contain chlorophyll are benefited by the action of small amounts of zinc which perhaps act as a catalytic agent in the metabolic processes.

Van Itallie and Van Eck (*4*) state that copper and zinc appear to be regular constituents of the liver. These metals were found in the newly born.

[1] Received for publication May 24, 1924; issued April. Read before the Division of Agricultural and Food Chemistry of the American Chemical Society at its meeting in Milwaukee, Wis., Sept. 10-15, 1923.

[2] Reference is made by number (italic) to "Literature cited," p. 196.

In a stillborn child there were 26.1 mg. of copper and 73.9 mg. of zinc per kilogram in the liver.

The author (*8, 9, 10, 11*) has shown that manganese is an essential element in the growth of autotrophic plants and functions in the synthesis of chlorophyll, for when this element is carefully excluded from sand culture experiments plants do not synthesize chlorophyll and, consequently, make very little growth.

EXPERIMENTAL DATA

SOILS

Preliminary experiments on a few virgin soils from the more important soil areas of Kentucky show that they contain amounts of the elements arsenic, copper, antimony, manganese, zinc, nickel, cobalt, barium, and strontium large enough for estimation by the usual methods of qualitative chemical analysis applied to the hydrochloric acid extract from 1,000 gm. of air-dried soil. The purified precipitates obtained in the analysis of the solution from one virgin soil gave the following quantitative results in parts per million of the element in the air-dry soil:[3] Arsenic 10.8, copper 7.2, zinc 27.7, cobalt 1.5, nickel 3.9. The presence of these elements in a Kentucky soil in greater quantities than was anticipated suggested further investigations as to their presence in certain parts of plants and animals which had received their sustenance from the soil in which these elements occur.

PLANT SUBSTANCES

Thus far the foliage and seeds of a few of the more important farm crops have been examined for some of the so-called nonessential elements. The ash resulting from the incineration of 1,500 gm. of air-dry corn silage was digested in hot 20 per cent hydrochloric acid. The insoluble material was filtered and washed free of chlorides. The hydrochloric acid solution of the ash was examined by the usual procedure of qualitative chemical analyses and the following elements were found: Arsenic, appreciable; lead, trace; copper, appreciable; manganese, considerable; zinc, appreciable; nickel, trace; barium and strontium, appreciable.

Samples of the following materials were analyzed:

Kentucky bluegrass (*Poa pratensis*): A clean, hand-picked sample of the fresh blades which were about 6 to 10 inches in length. The blades of grass were free from soil or other extraneous matter.

Soybean leaves: Fresh leaves were hand picked from the upper half of plants about 3 to 4 feet tall, growing in the field. The leaves were free from soil or other visible extraneous matter.

Soybean seeds: The seeds were clean and mature, and were grown on the same farm and the same type of soil as the soybean leaves but not on the same plants.

Wheat bran: A sample of wheat bran from a red winter wheat was obtained at a flour mill. The bran was freed from the germs and small particles of bran by shaking in a 20-mesh sieve and selecting the larger flakes of bran that remained on the sieve for the analysis.

Wheat germs: This material was not absolutely pure wheat germs but was a representative sample of the material designated as wheat germs by the miller. It contained small particles of bran and some flour. Perhaps the germs formed as much as 70 per cent of the mixture.

Patent flour: The sample represented the highest grade of patent flour and was produced at the same mill at which the wheat bran and wheat germs were obtained.

Corn germs: The corn germs were dissected by hand from sound, mature grains of white Hickory King corn, which had grown on the Kentucky Agricultural Experiment Station farm, at Lexington.

Corn endosperm: The remaining part of the corn grains was used from which the germs had been cut out by hand with a small gouge.

Rice polishings: A sample of the commercial material containing the pericarp and germ of the rice grain, removed from the grain in the process of polishing.

Polished white rice: The commercial product from which the pericarp and germ have been removed in the process of polishing was selected.

It is evident from the data in Table I that when the cereals, wheat, corn, and rice are highly milled by modern processes, the finished products, patent flour, degermed corn meal, and polished rice, are practically freed from copper, manganese, zinc, and iron. It is interesting to note that the germs of wheat and corn are relatively rich in copper, manganese, and zinc, thus showing a close association of these elements with the vital part of these grains.

[3] Methods of estimation (*14*): Arsenic, Gutzeit Method, page 46; Copper, ammonia method, page 167; Zinc, precipitated as sulphide in CH_3COOH and weighed as sulphate, p. 479; Nickel, dimethylglyoxime method, p. 287; Cobalt, nitroso-beta-naphthol method, p. 143

TABLE I.—*Metals found in vegetable substances, expressed in parts per million of moisture-free material*[a]

Material	Copper	Iron	Manganese (*15*)	Zinc	Nickel	Cobalt
Bluegrass (*Poa pratensis*)	7.5	336.0	30.0	28.0	Trace	Trace
Soybean leaves	8.0	336.0	160.0	110.0	Trace	Trace
Soybean seeds	12.0	70.0	32.5	18.4	3.92	Trace
Wheat bran	16.0	210.0	125.0	75.0		
Wheat germs	46.0	270.0	150.0	160.0		
Patent flour	Trace	24.0	10.0	Trace		
Corn germs	10.0	270.0	40.0	103.0		
Corn endosperm	Trace	30.0	16.0	Trace		
Rice polishings	7.0	168.0	100.0	70.0		
Polished rice	Trace	3.0	10.0	Trace		

[a] The data in Table I, except those for manganese, were obtained by methods described by Scott (*14*), using the hydrochloric acid solution of the ash from 100 gm. of air-dried material, except the soybean seeds, of which 500 gm. were used. Manganese was determined by the periodate method (*15*) in a separate portion of 10 gm. of material.

TABLE II.—*Metals found in animal substances; expressed in parts per million of the moisture-free material*

Material	Copper	Iron	Manganese	Zinc
Lean meat of ox	0.4	225.0	Trace	15.0
Liver of same ox	75.0	308.0	15.0	112.0
Liver of calf one week old	345.0	168.0	14.0	122.5
Blood of same calf	8.0	1,720.0	Trace	32.0
Testicles of a mature horse	154.0	221.0	12.0	55.0
Egg yolks	2.5	100.0	1.5	67.0
Cod liver chum	44.0	173.0	4.0	92.0

ANIMAL SUBSTANCES

The foregoing observations and results on the occurrence of copper, manganese, and zinc in the foliage and seeds of important agricultural plants suggested further investigations on their occurrence in the tissues and fluids of domestic animals. The method of procedure used for all animal substances was substantially the same as the following, used for lean meat of an ox. A sample of lean meat from a freshly slaughtered mature normal ox was obtained, run through a meat chopper, and dried at 100° C. One hundred grams of the moisture-free lean meat was heated gently in a clean quartz dish until no further volatile matter was given off. The carbonized matter was then digested with hot 20 per cent hydrochloric acid and ground fine in a porcelain mortar, transferred to a Buchner funnel, filtered and washed with hot water. The remaining residue of carbonized matter was returned to a quartz dish and further ashed at a temperature below redness in a muffle furnace. This method of alternate ashing and extraction with acid and water was repeated until all the carbon was consumed and the mineral matter contained in the meat was in solution. The solution was made to a definite volume and aliquots taken for the estimation of the different elements reported in Table II

DISCUSSION OF RESULTS

From the results contained in this preliminary report it is evident that small amounts of copper, manganese, zinc, nickel, and cobalt are widely distributed in soils and plants. Each of these elements has been found in larger amounts than was anticipated in samples of soil from a few of the larger geological formations in Kentucky.

Examination of plants grown under natural conditions in the soil have revealed the presence of copper, manganese, and zinc in every case and in larger amounts than were anticipated. Nickel and cobalt occur in some of these plants in sufficient amounts to permit quantitative determination of these elements when not more than a kilogram of the dry plant material is ashed and these elements are carefully sought, using standard methods of chemical analysis.

The fact that the liver of a young calf contained so much copper is both interesting and significant. Since the calf was only a week old it must have obtained all this copper from the mother cow. The calf was apparently normal in every respect at the time it was slaughtered. The fact that the calf absorbed the amount of copper that it contained from the mother cow raises the question as to the effect on the offspring if the food of the mother cow

had been deficient in either copper, manganese, or zinc. The author is seeking a definite answer to this question by experiments both with plants and with small animals. It has been known for a long time that copper is of common occurrence in the tissues of land and marine animals. It is stated that copper replaces the function of iron in the metabolism of some of the lower forms of animal life. It is a well known fact that inorganic compounds of copper, manganese, and zinc have important catalytic functions and it is not unreasonable to assume such a rôle for the organic colloidal complexes of these metals in the metabolic processes of plants and animals.

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